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An Inquiry,

ADDRESSED TO THE INTERNATIONAL ASSOCIATION FOR OBTAINING A UNIFORM DECIMAL SYSTEM OF MEASURES, WEIGHTS, AND COINS;

WITH ANSWERS FROM THE BRITISH BRANCH OF THE ASSOCIATION,

SHEWING THAT

THE BEST UNIT OF LENGTH IS THE METRE.

By James Yates

"In the dimensions of the earth we find a natural unit of the measure of space, which possesses in perfection every quality that can be desired."

SIR JOHN HERSCHEL, *Discourse on Natural Philosophy*, p. 126.

"One need only cast an eye over the system (founded on the metre and used in France) to see at once the great advantages that it possesses over the complicated systems of any other country. Not only is it incomparably more simple for all the practical purposes of life; but it assimilates at once all those rules in arithmetic, classed under the terms Compound Addition, Subtraction, Multiplication, and Division, reducing the whole of arithmetic to the first simple rules. A child, under this system of Weights and Measures, may learn everything necessary for entering into the common concerns of the world in a month, as well, and better than in a year under our complicated system."

PROFESSOR BARLOW, of Woolwich.
Mathematical Dictionary, Lon. 1814, art. MEASURES.

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PREFACE.

THE British Branch of THE INTERNATIONAL ASSOCIATION FOR OBTAINING A UNIFORM DECIMAL SYSTEM OF MEASURES, WEIGHTS, AND COINS, has recently taken a very important step by the adoption of the following REPORT in favour of the METRE as THE UNIT OF LENGTH.

The Essay, which follows the REPORT, was read and discussed at four successive meetings of the Association. It contains all the facts and considerations, which presented themselves as conducive to a right solution of the main question, and which were arranged under twelve distinct inquiries. For the accuracy of the facts and citations, and for the authorship of the Essay in general; the individual, whose name is subscribed, holds himself responsible. At the same time he produces it as having the sanction of the Society, which requested its publication, listened to it with great attention, suggested certain improvements, and finally expressed a warm and unanimous approbation of the Report, which is based upon it, and which is in fact a summary of its contents.

In an inquiry so varied and extensive, it would be presumptuous to lay claim to perfect accuracy. The author hopes that his Essay will again have the benefit of a revision by many and most competent judges, so that its mistakes, if there are any, may be corrected, and its deficiencies supplied. In a future edition he will thankfully insert any additional facts

and observations, which shall be properly authenticated and shall appear to be conducive to the further elucidation of the subject.

The Society, having adopted the Report at their Annual Meeting in February last, further instructed the Council to pursue their inquiries in the same direction, and also to proceed to the consideration of Weights and Measures of Capacity. It is required, that these should be based on the Metre, so as to become part of the same Decimal and International System. An arduous task is thus imposed upon the Council. In order to execute it, the first step will probably be the preparation of a series of questions bringing into view all points of importance; and, in obtaining replies to these questions and determining the course of further proceedings, it is the wish of the Council to secure the co-operation and advice of Municipal Corporations and Market Towns, of Philosophical and Scientific Societies, of Chambers of Commerce, and of Agricultural and Commercial Associations. Communications on the subject may be addressed to Mr. Henry Wright, Assistant Secretary, at the Office of the Association, 11, Buckingham Street, Adelphi, London.

In the following Report, and in the Essay subjoined to it, no arguments are introduced in favour of the Decimal scale or of the International principle. These are here taken for granted. The concern of the Council now is to recommend a series of Weights and of Measures of Capacity, derived from the Metre, produced by decimal multiplication and division, and adapted for universal use.

JAMES YATES.

HIGHGATE, NEAR LONDON,
May 1*st*, 1858.

REPORT ON THE UNIT OF LENGTH,

PRESENTED BY THE COUNCIL TO THE SECOND ANNUAL GENERAL MEETING, HELD FEBRUARY 25TH, 1858, AND ADOPTED UNANIMOUSLY.

At the First Annual General Meeting, held February 26th, 1857, the following Resolutions were adopted:

"That this Meeting regards as the first essential step towards arriving at a Uniform System of Measures, Weights, and Coins, which shall be International as well as Decimal, the adoption of THE BEST UNITS OF LENGTH AND OF WEIGHT.

"That the Council be requested to make inquiries and to collect information on these two subjects, with a view to the attainment of useful, definite, and practical results.

"And that, if the Council and the Members of the British Branch Association in general, are able to arrive at a conclusion on either of these points, they be authorized to request the General Officers of the Association to summon a Fourth General Meeting of the Central Association, and to obtain for it the concurrence of Her Majesty's Government and of the principal commercial nations of the world; and that the object of this General Meeting be to consider the adoption of any plan, which may be recommended either by this Branch Association or by those of other countries."

In order to comply with this request, a set of questions was printed and circulated, with a view to obtain all desirable information relative to the BEST UNIT OF LENGTH, the question of the Unit of Weight being postponed until the preliminary inquiry had been finished.

A considerable number of answers were received; and as soon as the Council were able to reduce their deliberations and researches to a sufficiently definite form, they proceeded to call Meetings of the Members of the Association resident in London, and invited to these Meetings all persons who were known to be friendly to the general objects of the Association, and who were supposed to be interested in the subject and able to give valuable advice. Hence, both by letters received, and by the kind personal attendance of various gentlemen of scientific eminence and great practical experience, the Council have been enabled to arrive at a conclusion, which they can with full confidence recommend to the general body of the Association.

The first question was, whether they should adopt some new Unit, or fix upon a Unit already in use. No less than thirteen new Units, suggested either in published works or in letters to Members of the Council, came under review, in general evincing great ingenuity, diligence, and research, on the part of their inventors. It did not however appear, that any one of these had ever been applied in practice. The Council therefore decided to recommend some Unit, which was already in use, and which might be the best adapted to promote the general reception and permanent establishment of a uniform Decimal and International System.

On similar grounds they find themselves obliged to pass over the second's pendulum, the claims of which to preference were fully discussed. Notwithstanding the numerous experiments made in different parts of

the globe by philosophers of the highest ability, the exact length of the second's pendulum either under the Equator, or in any latitude N. or S. of the Equator, is still undetermined; nor does it appear that, since the proposal of Mr. Locke in 1679 to use the third part of the length of a reputed second's pendulum as a unit of linear measure, it has ever been adopted by any one for this purpose. No pendulum now exists which is proved and generally supposed to beat seconds with the requisite accuracy.

In consequence of the real or presumed relation of the linear measures of all ages and nations to the dimensions of the human body, the Council thought it right to inquire, what influence this consideration ought to have on their decision. Although they did not deem it advisable to fix upon the length or circuit of any portion of the human body, they adopted conclusions distinctly referring to its structure and functions. They thought it eminently desirable, that the Unit should be of such a length as might be adapted to measure the greatest variety of objects, and in the most numerous cases, which are likely to occur in daily life; that it should be visible at a glance of the eye, and easily carried about and manipulated by those who use it. It appeared that for these purposes an inch or a foot, much more any subdivision of these quantities, would be too short; that a fathom would be too long; but that the required conditions would be best fulfilled by any measure about the same with the ell, the metre, the second's pendulum, or the yard.

In relation to another much-controverted subject,

the Council thought it requisite, in conformity with the aim of an International Association, to avoid the appearance of undue partiality to English habits, and that a natural standard, adapted as far as possible to the ideas of all countries throughout the world, ought to be preferred to any, which has been employed from merely traditional, arbitrary, or accidental causes. Indeed, it appeared that, even if the English yard were chosen, very little benefit would ensue, because no decimal multiples or divisions of the yard are anywhere in use, and consequently a set of linear measures must be devised entirely new, with the single exception of the yard itself.

The Council were thus brought of necessity to the special consideration of the claims of the metre.

They first examined at length the objections to the metre on the ground of its supposed inaccuracy. They found that some of these objections are entirely without foundation, and that others are insufficient to justify its rejection. The advance of science, the improvements in astronomical instruments, and the repetition of attempts to measure meridians, although they may lead to some very minute alterations in the length of the metre, or in its assigned standard temperature, tend on the whole to establish its accuracy. It is impossible to measure with perfect exactness any material object. We ought to aim at the utmost attainable perfection, but still to allow a degree of latitude, so that a measurement may not be condemned because it may possibly differ by the hundred thousandth part from the real truth.

The attention of the Council was also called to certain alleged defects in the construction and preservation of THE METRE, meaning hereby the bar of platinum, which became the prototype in 1799, and which is still preserved in its original depositary at Paris. It is hoped that, if the metre is finally adopted by this country as its unit of length, provision will be made for the due correction of any minute, accidental, or unintentional defects.

The Council are of opinion, that, if by any accident the prototype shall be lost or destroyed, the metre may be restored without difficulty, not by a new measurement of a meridian, but by a reference to the numerous authorized copies dispersed over the world.

On proceeding to consider the metre with more especial reference to practice, the Council found that the metre has every quality which can be desired in a unit, which is to be employed as the basis of a Decimal and International System.

Its binary divisions go as far as can ever be wanted. Its subdivisions and its multiples are superior in utility and ease of application to those of any other system throughout the world.

Hence it is not surprising that the metre has made a remarkably rapid and extensive progress, being already adopted by about sixteen nations of greater or less commercial importance in both hemispheres. It appears, also, that the use of it is sanctioned by law in this country; that it is gradually becoming more known and appreciated; and that it has already come into use for a variety of purposes.

On the whole, the Council conclude, that its adoption is advisable, not only as the means of securing great political, social, and commercial advantages to the United Kingdom, but as a demonstration of a becoming desire to co-operate with other enlightened and powerful nations in the accomplishment of a generous design, which is urged upon public attention by the strongest appeals of reason and science, of patriotism and of philanthropy.

PRELIMINARY CONSIDERATIONS

RELATIVE TO THE QUESTION,

WHAT IS THE BEST UNIT OF LENGTH?

I. Is it better to seek for a new Unit, or to adopt one already in use?

Most persons think it better not to seek for a new unit, but to be satisfied with adopting the most eligible of all those which are already in use. The Commissioners, appointed at various times under the authority of the English Government, have been in general most decidedly opposed to the adoption of any new unit.

The only exception appears to be in the case of Mr. J. E. Drinkwater Bethune, one of the Commissioners appointed in 1838 to consider the restoration of the standards of length and weight. This gentleman drew up a separate Report in the form of a letter to the Chancellor of the Exchequer, by whom the appointment had been made. Among various proposals, in which he differs from his colleagues, he recommends as "the standard of length" a *new inch*, one hundredth part shorter than the present English inch. He appears to ground his proposal on the assumption, that Land measure is the most important of all measures, and that the other measures ought consequently to be formed by the division or multiplication of the chain of 22 yards; and then, by an imperfect decimalization

of the chain, he arrives at his new inch, which is the 800th part of the chain.*

Another new unit had been previously proposed by Sir Charles Pasley, who calls it *the new fathom*, because it does not differ very considerably from the present English fathom. It is based, like the metre, upon the measurement of the earth's circumference, but upon a calculation more recent and supposed to be more accurate than that which led to the determination of the metre. Sir Charles Pasley would take as his fathom the 1000th part of the minute of a degree, calculated according to the new measurement. One thousand of these new fathoms would be the new nautical or geographical mile, being the minute of a degree calculated as aforesaid. Also 1000 of these new fathoms would be equal to 1012.715 of the old fathoms now in use.†

Another proposal, not very unlike the last, is to take an aliquot part of the earth's axis. In England the metre is sometimes objected to, because the arc of a terrestrial meridian, from which it is derived, crosses France from Dunkirk to Spain, was measured by Frenchmen, and is deduced from a triangulation, having the Pantheon of Paris at one of its angles. It is argued, that a portion of the earth's axis would not belong to France more than to any other country, and consequently could not be the object of national antipathy. Professor Hennessy, of Dublin, though himself in favour of the metre, has calculated the length of the unit here suggested, being of opinion, that if it

* Letter to the Chancellor of the Exchequer, Dec. 1841, pp. 2, 3.

† See Sir C. Pasley's "Observations," London, 1834, 8vo, pp. vii and 5—7; and his "Plan for simplifying and improving the Measures, Weights, and Money of this Country, without materially altering the present Standards," published in the Assurance Magazine, Vol. VI. p. 242.

were necessary to abandon the metre out of regard to insuperable national prejudices, this would be preferable to any other new standard. No one, however, insists upon it, and, if it were attempted, it would soon be found that it does not remove the difficulty. For it is impossible to measure the earth's axis, except by deducing it from arcs measured on the earth's surface, so that England would be compelled to jostle against France, or some other nation, exactly as before.

A suggestion, which is substantially the same with Mr. Bethune's, although devised without any communication and by a completely different process, has been kindly submitted to the writer of these pages by Serjeant-Major P. Casey, of Fulwood Barracks, in Lancashire. He proposes as the unit of length *a new metre* of 39.6 English inches, being the 40.000.000th part of the Equator estimated at a sufficient elevation above the level of the sea. His "English metre" is exactly the fifth part of the rod, pole, or perch, and equal to five links of the chain.

Mr. John Taylor, of Kensington, in a most learned and ingenious treatise not yet published, proposes "*the Pyramid metre*," being 39.2724 English inches, about one-four-hundredth shorter than THE METRE. He explains its relation to the measures, which appear to have been used in constructing the great Pyramid, to the measurement of a meridian in Egypt, and to the principal linear measures of the ancients.

A new unit of length, founded on an entirely different basis, is proposed by Mr. Jessop, of St. John's College, Cambridge, in the following terms:

"The standard of length is the digit, which is one-sixty-fourth part of the length of a pendulum, oscillating in a second, in a vacuum, at the level of the sea, in the latitude of Greenwich."

Mr. Jessop calculates, that 100,000 such digits would make a mile, being only about one-twenty-seventh less than the English statute mile, and he considers this as the great advantage of the system.*

Mr. K. J. W. Paulson suggests "the introduction of a new *rod*, the decimal multiple of the foot."†

Mr. Aslits recommends, that the foot itself should become the unit instead of the yard.‡

Mr. Henschel, an engineer at Cassel, in Germany, proposes a new *pace*. Its length is eight decimetres, and the series of linear measures derived from it is identical with those of the Metrical System, except that a length exactly equal to four-fifths of the metre is assumed as the unit instead of the entire metre.§

Within a few months, a new unit has been proposed by Mr. J. Simon Holland, of Woolwich. It is the sixteenth part of an inch, and he makes this the basis of

* "A Complete Decimal System of Money and Measures," by W. H. R. Jessop, Cambridge, 1855, pp. vi, 15—17.

At the Special Meeting of the Association, held Dec. 2, 1857, Mr. Jessop stated his view to be, that by proceeding from a very low unit, decimal multiplication is sufficient without division. This would of course simplify all arithmetical operations. It was, however, the general opinion that division is as necessary as multiplication, and that linear measures far lower than Mr. Jessop's digit are required in many cases. The unit proposed by Mr. J. S. Holland is far smaller than Mr. Jessop's; and yet Mr. Holland's *steen*, the sixteenth of an inch, would require to be divided into tenths and probably into hundredths. Mechanicians have occasion to provide for lengths too minute to be perceived either by sight or touch. It appears therefore indispensably necessary that the unit should not be at the bottom of an ascending series, but a middle term, admitting both of multiplication and division, and as far as possible to an equal extent.

† "Decimalism, by a Commercial Traveller," p. 22. In Dickens's Household Words, Nov. 1855, we find a new edition of the remarks of the Commercial Traveller, but with a decided recommendation of the metre: "I say, 'Cut the knot at once; throw away the yard measure, and seize the metre.'"

‡ "Decimal Coinage," London, 1854, pp. 36—38.

§ "Das bequemste Maas-und Gewichtssystem gegründet auf den natürlichen Schritt des Menschen," Cassel, 1855.

"a system perfectly decimal in its entire construction," and including measures, weights, and coins.*

I am not aware that any one of these proposals has met with the slightest countenance. In short, I believe, the prevailing opinion is most decidedly in favour of adopting some unit, which is already in use.

II. IS IT BETTER TO ADOPT A UNIT FOUNDED IN NATURE, OR TO TAKE ONE WHICH IS ENTIRELY ARBITRARY, HAVING NO SPECIFIC RELATION TO ANYTHING NATURAL, BUT HAVING COME INTO USE FROM ACCIDENTAL CAUSES?

The answer given to this question by different parties appears to depend on their adoption or rejection of the international principle.

The English Commissioners, above referred to, have always rejected natural standards, and have never entertained the international principle. Those, for example, who reported in 1819, assert that there is "no sufficient reason for altering the standards of length generally employed, as there is no practical advantage in having a quantity commensurable to any original quantity existing, or which may be imagined to exist, in nature, except as affording some little encouragement to its common adoption by neighbouring nations."†

When, on the other hand, the great experiment was made, which ended in the adoption of the metre as the unit of length to be proposed as suitable for all nations, it was decided to abandon the French *aune*, and every other national and local measure, in order

* Mechanics' Magazine for August 22, 1857, p. 176.

† Edinburgh Phil. Journal, Vol. I. p. 426.

that some measure might be chosen, which would not be appropriate to any one country more than to any other, but which might be accommodated as far as possible to the ideas and habits of all countries equally. To accomplish this, it was necessary to fix upon some permanent quantity in nature; and there are two quantities of this kind, which have divided the choice of all politicians and philosophers, who have aimed at an international method. These are, 1st, the length of the pendulum vibrating seconds in a certain latitude; and, 2ndly, the chord of an arc, which is a certain portion of the earth's circumference.*

The 15th of March, 1816, was a memorable day in the annals of British legislation on the subject of Weights and Measures. Then was the first dawn of liberal and enlarged conceptions, after ages of ignorant and narrow-minded devotion to established national practices. The accurate science of Parliament was concentrated in one amiable, candid, and accomplished man, Mr. Davies Giddy, afterwards better known as Mr. Davies Gilbert, M.P. for Bodmin. On the above-mentioned day he proposed and carried the following Resolution in the House of Commons:

* Dr. Lamont, Astronomer Royal of Bavaria, and Dr. W. H. Miller, of Cambridge, have suggested that the undulations of light might be made to afford a better standard; but I am not aware that the suggestion has hitherto been reduced to a system, much less attempted in practice, although Fraunhofer's discovery of the lines in the prismatic spectrum was made more than forty years ago. See "Report of the Commissioners on the Restoration of Standards," 1841, pp. 28, 29. "Denkschriften der k. Academie der Wissenschaften zu München," 1815. "Edinburgh Phil. Journal," Vol. VII. p. 178; Vol. IX. pp. 296—299. Prof. Baden Powell, in Thomson's "British Annual," 1837, pp. 162—210.

Lamont, in the "Jahrbuch der k. Sternwarte bei München" for 1838, p. 212, supposes one metre to be equal to 1698450 waves of light, observing, however, that he gives this number only by way of illustration, not as accurately true to nature.

"That an humble Address be presented to H. R. H. the Prince Regent, that he will be graciously pleased to give directions for ascertaining the length of the pendulum vibrating seconds of time in the latitude of London, as compared with the standard measure in the possession of this House, and for determining the variation in length of the said pendulum at the principal stations of the Trigonometrical Survey extended through Great Britain, and also for comparing the said standard measure with the ten-millionth part of the quadrant of the meridian, now used as the basis of linear measure on the continent of Europe."*

By command of H. R. H. the Prince Regent, this Resolution was communicated by the Secretary of State for the Home Department to the Council of the Royal Society, who resolved to take every measure in their power to comply with the request, and appointed a Committee for the purpose, consisting of Sir Joseph Banks, the President of the Society; Mr. Giddy, the prime mover in the proceeding; Mr. Pond, the Astronomer Royal; and nine other Fellows, who were the most eminent in physical science. The result of the inquiries of these Commissioners and of a few others subsequently added to their number, was a Report made on the 13th of July, 1820, in which they conclude "that the length of the pendulum vibrating seconds in a vacuum, on the level of the sea, in London, is 39.13929 inches, and that of the metre 39.37079 inches, the English standards being employed at 62 deg. of Fahrenheit."†

As there will be occasion to refer to these proceedings hereafter, they are only introduced here as evidence, that the second's pendulum and the metre are regarded by the highest authorities in this country,

* Journals of the House of Commons, Vol. LXXI. p. 202. Mr. William Watts, in Edinburgh Phil. Journal, Vol. I. p. 326. Weld, Hist. of the Royal Society, Vol. II. p. 253. Phil. Trans. for 1818 and 1819.

† Weld, p. 263. Phil. Trans. for 1818, pp. 93, 109.

both political and scientific, as the only natural standards adapted to serve as a basis for any metrological system.

Those countries, which have not adopted the international principle, have always adhered to some arbitrary or accidental measure as their unit. Thus England has its *yard*, Rome and Naples a *palm*, other parts of Italy a *braccio* of various dimensions, and Germany a *foot*, which differs in length in different parts of Germany. Where union is not attempted, disunion is the inevitable result. Each nation, having regard to its own sole convenience, chooses some measure, to which it is accustomed, and makes that its unit of length.

The advocates of these arbitrary units may, however, allege, that there is a prospect of some one of them becoming universal in consequence of the great extension, which it has already acquired. But those who argue on the solitary, in opposition to the international principle, will of course prefer their own individual habits. How, then, is it possible for them to attain to uniformity? China, with its population of 350 millions, will not follow Russia with only 60 millions, nor will Russia join Prussia with a still smaller population.

It therefore appears, that for us, Members of an *International Association*, the second Question, here proposed, is already solved by the principle, on which we are united. We must choose for our unit of length some natural standard, and our choice apparently lies between two, the second's pendulum and the metre.

In the early volumes of the Edinburgh Review, there is an admirable series of essays by Professor Playfair respecting the adoption for all nations of a

uniform system of Measures, Weights, and Coins.* In one of these we find the following remarks:

"The want of system in the weights and measures of every country; the perplexity which that occasions; the ambiguous language it forces us to speak; the useless labour to which it subjects us, and the endless frauds which it conceals, have been long the disgrace of civilized nations. Add to this the perishable character thus imprest on all our knowledge concerning the magnitude and weight of bodies, and the impossibility, by a description in words, of giving to posterity any precise information on these subjects, *without reference to some natural object that continues always of the same dimensions.* The provision, which the art of printing has so happily made for conveying the knowledge of one age entire and perfect to another, suffers in the case of magnitude a great and very pernicious exception, for which there is no remedy but such reference as has just been mentioned. Philosophers had often complained of these evils, and had pointed out the cure. But there were old habits and inveterate prejudices to be overcome; and the phantom of innovation, even in its most innocent shape, was sufficient to alarm governments conscious that so many of their institutions had nothing but their antiquity to recommend them. At the commencement of the French Revolution the National Assembly was avowedly superior to the last of these terrors, and the philosophers of France considered it a favourable opportunity for fixing, with the support of Government, a new system of measures and weights on the best and most permanent foundation."†

* Edinburgh Review, Vol. V. p. 372. "An Account of the Operations carried on for accomplishing a Trigonometrical Survey of England and Wales." By Capt. Mudge. In Phil. Trans. 1799.

Vol. IX. p. 373. "Base du Système Mètrique Décimale, ou Mésure de l'Arc du Méridien entre les Paralleles de Dunkerque et Barcelone." Exécutée par MM. Méchain et Delambre. Tome Premier. Paris, 4to, 1806.

Vol. XXI. p. 310. "An Account of a Trigonometrical Survey, and of the Measurement of an Arc of the Meridian in the Peninsula of India." By Major Lambton. From the "Asiatic Researches," Vols. VIII. X. and XII.

Vol. XXX. p. 407. "An Account of Experiments for determining the Length of the Pendulum vibrating Seconds in the Latitude of London." By Capt. Henry Kater, F.R.S. From the Phil. Trans. London, 1818.

The four articles, above referred to, are reprinted in the fourth volume of Playfair's Works, which appeared soon after his death in July, 1819.

† Ed. Rev., Vol. XXX. p. 409. Playfair's Works, Vol. IV. p. 505.

III. Is any Unit of Length entitled to preference on account of its correspondence with the dimensions of the human body?

It is exceedingly important that the unit should be a length fitted for the most frequent and general application in measuring all kinds of objects; that it should be wholly visible at a glance of the eye; easily carried about and readily manipulated. For these purposes it seems desirable, that it should be such that any grown-up person may without effort hold it between his two hands, as a draper or mercer does in measuring cloths, tapes, ribbons, or goods of any kind. If it were possible to determine what length is employed more frequently than any other in measuring objects and commodities of all sorts, that length might be taken, not only as the quantity most familiar to the mind as well as commodious to the hands, but also as the proper middle term, the multiples of which would come into use for all greater lengths, while the subdivisions of the same fundamental quantity would express the smaller extensions with all desirable accuracy.

This medium length, so suitable for the unit, may be either exceeded, or the contrary. Sir Charles Pasley's new fathom, a little longer than the English fathom, would, in my opinion, be considerably too long, not being fitted for measuring the commonest objects in the manner above described, although it might not be ill adapted for soundings at sea, and for measuring the depth of mines, for roads, and for other geographical purposes. On the other hand, some nations have adopted too small a unit, such as the *palm*, the *span*, the *cubit*, which was the unit of the

ancient Egyptians and Hebrews, and the *foot* of various dimensions, derived probably from the ancient Roman foot, and retained by the Germans, the Russians, and other continental nations.*

But notwithstanding the extent, to which the foot and other comparatively small measures have been adopted or recommended as units, we find at least an equal amount of authority in favour of one considerably longer. The *ell*, the *yard*, the *vara* of Spain and Portugal, the Italian *braccio*, the Persian *arish*, the *gez* or *guz* of Arabia and India, the *metre* and the *second's pendulum*, may be regarded as having all nearly the same length, and all nearly fulfilling the conditions, which I have represented as so important. If a choice were to be made, I think it should be in favour of the metre; for it is a little longer than all the other six measures here mentioned, except the ell, and equally manageable. If the yard is perhaps a trifle too short for perfect convenience, the ell, on the other hand, is too long, inasmuch as persons, more especially females, cannot stretch their hands far enough apart to use it with sufficient ease and quickness. Sir Charles Pasley, so noted for his attention to these questions, and anything but an admirer of the metre, observes, nevertheless, that "it is a more convenient measure for cloth than the old French *aune*, which was rather too long for that purpose."†

An important testimony in favour of the longer measure seems to have been given by implication in

* Sir J. R. Miller, whose zealous and enlightened attempt to introduce a Decimal and International System will be mentioned hereafter (§ iv. p. 14), observes, that "a very small error is considerable on a small scale or standard, while a much greater error on a large scale is inconsiderable."

† l. c. p. 253.

the decision of the Prussian Government. In constructing their new standard of length, they retained the Rhenish foot as a basis, but took three of these feet for their standard, adopting a metallic rod of that length, terminated by sapphires to preserve it from change. The consequence is, that their new standard of length is a little longer than the yard, and comes nearer to the metre.

IV. Is the Pendulum, vibrating seconds in a certain latitude, eligible as the Unit of Length?

The very striking and ingenious idea of employing the pendulum as the universal basis of linear measures, probably first occurred to the Dutch philosopher, Huygens, who explains it in his *Horologium Oscillatorium*, published in 1673. It is, however, ascertained, that Sir Christopher Wren and his philosophical friends in the newly-formed Royal Society of London, were occupied with the same experiments, and corresponded with Huygens on the subject.* But Huygens, besides having at least an equal claim to priority, both studied the matter and published his views upon it very fully. He discovered the rule for finding the centre of oscillation, and proposed for the unit of length a foot equal to one-third of the second's pendulum, which foot soon became the basis of a very exact decimal system of linear measures, as we learn from the following remarkable passage in a letter of Mr. Locke to the Hon. Robert Boyle, dated June 16th, 1679:

* Wren had made experiments on the pendulum as early as 1660. Bishops Wilkins and Sprat attribute the invention to him. See Weld's "Hist. of the Royal Society," I. pp. 67, 96. Also a very valuable Memoir by Mr. Grant in the Monthly Notices of the Royal Astronomical Society, XV. pp. 36—39; and Abbé Moigno's "Cosmos," 1855, 9 Fevrier, p. 151.

"Before I conclude I must not forget to tell you that the measure I made use of was the philosophical foot, i. e. $\frac{1}{3}$ of a pendulum of seconds, which I divided thus; the foot into ten inches, the inch into ten lines, the line into ten grys; so that a gry is one-thousandth part of P.P.; which measure, whatever it be for other purposes, I thought the fittest for philosophical communications, and therefore made use of it in this and several other occasions. But I have troubled you too long already to mention here the conveniencies of this foot, and (as I think) of the way of dividing it by decimals."*

Sir James Steuart, of Coltness, the distinguished author on Political Economy, wrote "A Plan for introducing a Uniformity of Weights and Measures over the World." It was published after his death, which occurred in 1780. It contains many valuable thoughts, and proves the great attention which the author had bestowed upon the subject. He is decidedly in favour of abandoning all former weights and measures, in order that a good system may be established. For this purpose he recommends as the unit of linear measure the length of the pendulum, which vibrates seconds in the latitude of London, and advises that its multiples and divisions should be decimal.†

Dr. George Skene Keith, an Aberdeenshire clergyman, adopted the views of Sir James Steuart, and prosecuted the subject during thirty years with great zeal and assiduity.‡ Soon afterwards, the length of the second's pendulum in 45 deg. N. latitude on the meridian of Skagen was adopted as the standard for Denmark and Hamburg.§ In 1822, Mr. Robert Wallace, a teacher of mathematics, published at Glasgow

* Boyle's Works, folio, 1744, Vol. V. p. 570. A few years later, Locke published the same scheme of Decimal Measures, in a note to his "Essay concerning Human Understanding," b. iv. chap. x. § 10.

† Sir James Steuart's Works, Vol. V. pp. 380—415.

‡ See his pamphlets published in 1791 and 1817.

§ Quarterly Journal of Science, No. XXI. p. 184.

a very valuable treatise recommending that for the same purpose the length of the pendulum should be ascertained at the Equator.* But among all the advocates of the pendulum none deserves more honourable mention than Sir John Riggs Miller, an Irish Baronet, who, in order that he might collect information and promote reform, sat in Parliament for one of the lowest of the rotten boroughs; received more than a thousand letters; obtained the appointment of a Committee to investigate the actual state of the weights and measures used throughout England; and exposed their faults in two speeches more clear, powerful, and conclusive than any others upon the subject. His efforts were abruptly terminated by the dissolution of Parliament, so that England remains in the same disgraceful condition, which he so eloquently and faithfully exposed.†

* "Observations on Weights and Measures, containing a Plan for Uniformity on a Philosophical Standard," &c. Glasgow, 1822.

† Sir John Riggs Miller was returned for Newport, in Cornwall, A.D. 1784. His speeches may be found in Hansard, Vol. XXVIII. Their dates are July 25th, 1789; Feb. 5th, 1790; and April 13th, 1790. At the same time he published them entire as a pamphlet, with some other very important documents. To indicate its contents, I quote the title entire:

"Sir John Riggs Miller's Speeches in the House of Commons upon the Equalization of the Weights and Measures of Great Britain, with Notes; also a General Standard proposed for the Weights and Measures of Europe: with Brief Abstracts of the most material Acts of the British Legislature, and other Ordinances and Regulations for the Equalization of our Weights and Measures from Magna Charta; together with Two Letters from the Bishop of Autun to the Author upon the Uniformity of Weights and Measures, the Prelate's Proposition respecting the same to the National Assembly, and the Decree of that Body of the 8th of May conformable to the Bishop's Proposition, with English Translations."

Talleyrand's two letters, herein mentioned, will be quoted below, pp. 17—19.

The entries in the Journals of the House of Commons of the above dates, and also of April 1st, 1790, shew that Parliament then obtained to a considerable extent the same evidence on *local* weights and measures, which has been recently obtained by the International Association.

The adaptation of the pendulum as the foundation of a system of linear measures being one of the most exact and beautiful portions of physical science, it is gratifying to know that it was further countenanced by the vote of the House of Commons on the 15th of March, 1816,* and that English philosophers have in consequence prosecuted the experiments and observations pertaining to it with distinguished ingenuity, zeal, and accuracy. Hence it is believed by some competent judges, that the length of the pendulum, as described in the terms of the question, is ascertained, so that it may be safely assumed to be the true quantity intended.

Nevertheless, the action of gravitation, on which the time of the vibrations depends, is subject to so many variations and disturbances, that the quantity sought cannot, even on the same spot of ground, be absolutely the same at all times. Suppose that, during the late Crimean campaign, the vibrations had been counted at Sebastopol. The assemblage of men, ships, cattle, tents, dwellings, armaments, and all other heavy substances collected in that vicinity, would have produced a different result from that to be observed at the present moment, and yet all these masses of matter collected together would be insignificant compared with the lava ejected from a single volcano. But suppose the observer to erect his pendulum on a spot free from every subterranean commotion, and to repeat his observations an immense number of times, so that by taking an average of the whole he may ensure the greatest possible certainty of success. Still variations of the atmosphere, which always contains large stores of water in different states, floating here and there,

* See above, p. 7.

changing in quantity every hour, and often falling to the ground, must affect his instrument, if its accuracy is to be trusted.* It appears, therefore, impossible to assign a length to the second's pendulum, which shall be in the same latitude, or even in the same place, its exact length at all times. We can only hope to arrive at a very near approach to such a length.

The aim of the Resolution of the House of Commons, above cited, and of the Council of the Royal Society in carrying it into effect, was to determine the length of the second's pendulum in London and in other parts of Great Britain. This was considered sufficient for a merely national purpose. The French Academicians, as their views were more extensive, have recommended that the length should be calculated for the Equator and for the parallel of 45 deg. These determinations would be more suitable to establish a unit of length intended to serve as the basis of a universal system. More especially the choice of the Equator, which was strongly recommended on this ground by La Condamine,† would have the further advantage, that the plane of the vibration of a pendulum, swinging East and West at the Equator, would coincide with the plane of the earth's rotation, and an important source of disturbance and error might thus be avoided, inasmuch as the diurnal motion of the

* The best ascertained case of local disturbance, arising from the vicinity of denser rocks, seems to be that of Arbury Hill. See below, pp. 28, 32. The granite there brought into play is 30 miles off. Its specific gravity is something approaching three times that of water. But its influence on the pendulum, being inversely as the square of the distance, will not exceed that of a quantity of water in the immediate vicinity of the pendulum, such as frequently falls in mist or in a heavy shower of rain, snow, or hail.

† "Rélation d'un Voyage fait dans l'Intérieur de l'Amerique Meridionale," Nouvelle Ed., 1778, p. 197.

earth would not interfere with the unconstrained motion belonging to the pendulum itself. If, therefore, the invitation offered by France to England, in 1790, to appoint an equal number of Fellows of the Royal Society to join the selected members of the French Academy in fixing this unit, had been accepted, it is highly probable that the second's pendulum would have been promoted to the place intended for it.* But as England did not respond to this generous offer, and the other European nations, which acceded to it, preferred taking a portion of the earth's circumference,

* The decree of the National Assembly, May 8th, 1790, was as follows:

"Le Roi étoit supplié d'écrire à S. M. Britannique, et de la prier d'engager le Parlement d'Angleterre à concourir avec l'Assemblée Nationale à la fixation de l'unité naturelle des mesures et des poids, afin que, sous les auspices des deux nations, des commissaires de l'Académie des Sciences pussent se réunir en nombre égal avec des membres choisis de la Société Royale de Londres, dans le lieu qui seroit jugé respectivement le plus convenable, pour déterminer à la latitude de 45 degrés, ou toute autre latitude qui pourroit être préférée, la longueur du pendule, et en déduire un modèle invariable pour toutes les mesures et pour les poids."—Delambre, "Base du Système Métrique, T. I. p. 14.

The particular form of this decree was adopted by Talleyrand, who proposed it, in compliance with the advice of Sir John Riggs Miller, who had already commenced his energetic attempt to arrive at the same object. The correspondence between these two statesmen was dictated by so enlarged a spirit of patriotism and philanthropy, that I must introduce it here as a very interesting addition to the history of this question. Sir J. R. Miller delivered his second speech, as already stated (p. 14), on the 5th of February, 1790. A few weeks afterwards, Talleyrand addressed to him a letter, of which the following is a translation:

"Paris, March 29th, 1790.

"Sir,—I understand that you have submitted to the consideration of the British Parliament, a valuable plan for the equalization of Measures. I have felt it my duty to make a like proposition to our National Assembly. It appears to me worthy of the present epoch, that the two nations should unite their endeavours to establish an invariable Measure, and that they should address themselves to Nature for this important discovery.

"If you and I think alike on this subject, and you are of opinion that much general benefit may be derived from it, it is through you only that we can hope for its accomplishment; and I beg to recommend it to your consideration. Too long have Great Britain and France been at variance with

the result has been, that the metre is now used as the unit of length by a large and influential portion of the

each other for empty honour or for guilty interests. It is time that two free nations should unite their exertions for the promotion of a discovery that must be useful to mankind.

"I have the honour to be, Sir, with due respect,

"Your most humble and obedient servant,

"THE BISHOP OF AUTUN.

"Sir John Riggs Miller, Bart.,
Member of the House of Commons, London."

Upon the receipt of this letter, Sir J. R. Miller wrote to inform the Bishop, that the only regular way of bringing the subject before Parliament was by a communication from the King of France to the King of England. At the same time the unexpected coincidence between their views was exceedingly gratifying to Sir J. R. Miller. His third speech, delivered after the Easter recess, commences as follows:

"April 13.—Sir *John Riggs Miller* rose. He said, he thought it his duty to acquaint the House, that since their late adjournment he had been honoured by a very flattering private letter from an eminent, learned, and very distinguished Prelate of a neighbouring nation, who had more than once presided with the most marked approbation in the National Assembly of France, approving his past and encouraging his future endeavours to obtain an equalization of Weights and Measures; and that letter was accompanied by a printed proposition, which had been addressed to the National Assembly upon that subject by the same Prelate. He said, the British nation should not be deprived of that great man's thoughts and expectations of success in the projected regulation, of the means which he proposes to be employed, and the assistance which he hopes to receive from the mutual co-operation of the British and French legislatures in the same investigations. Sir John said, it was very flattering to him that the public must hereafter perceive how much there was of coincidence and affinity between the learned Prelate's ideas and his own upon this intricate subject, without any prior communication whatsoever between them. The Bishop himself, indeed, had very liberally acknowledged in his private letter, that he took the hint of making his proposition to the National Assembly of France from what had been lately submitted to the British Parliament upon the same subject. The closing paragraph of that great man's private letter, so expressive of his patriotic feelings, and of his ardent wishes to see peace, harmony and goodwill established between two nations so long and so unhappily in rivalship with each other, to their own misfortune, as well as to that of a large portion of mankind, does his heart and his head too much honour to be withheld from the immediate notice of the House; and as it will not easily admit of an adequate translation, there needs no apology for giving it in his own words: 'Trop long tems les deux nations se sont divisées par de vaines pretensions ou de coupables interêts; il est tems, que deux peuples libres associent leurs efforts et leurs travaux pour une recherche utile au genre

human race, whilst the pendulum has never, probably, since the days of Locke been used as a linear measure, although admired for the beauty and approximate accuracy of the experiments made with it.

Even whilst I fully admit the skill and care bestowed upon these researches, I think them far from that precision, which may justly be required in such a case. If the metre is rejected for its alleged want of accu-

humain.' Sir John said, he should not avail himself of any new lights afforded by the Bishop of Autun's proposition, having for some time prior to his being honoured by that Prelate's communication arranged his own ideas upon the subject, which he should now submit to the House, and hereafter to the public, that the cause in which they were mutually engaged might have every possible consideration, and that the suggestions of the feeble might be discussed at the same time with the opinions of the strong, public utility being, he was satisfied, the ultimate end and object of both their endeavours and expectations."

Lastly, the Bishop, having sufficiently matured his project to carry it through the National Assembly, wrote to Sir John to inform him of the result in the following terms, at the same time transmitting a copy of the decree:

"Paris, May 12th, 1790.

"Sir,—I received with the utmost gratitude, and have read with the greatest eagerness, your dissertation on Weights and Measures, which you have had the goodness to send me; for which accept my most cordial acknowledgments, and be assured, that I feel myself happy in the so frequent coincidence of your ideas with mine upon that subject. I should be sorry you were apprized by any other than myself, that our National Assembly have taken into their consideration my publication upon this subject, and that the whole of my proposition has been adopted by them. I acquainted the Committee, who brought this business forward, with the communication which you had the goodness to make me, of the *only* channel through which the proposition could, *with propriety*, reach the British Parliament; and you will observe in reading the decree, which I have the honour to transmit you, that your observation has produced the desired effect. It is fit I should acquaint you, Sir, that the National Assembly has been particularly influenced, in the emission of its decree, by a unanimous desire of seeing a new connection established between the two nations, worthy of their common union in whatever can contribute to human felicity. I unite, Sir, with yours, my most ardent wishes for the extension of liberty, and for the propagation of true knowledge.

"I have the honour to be, &c. &c.

"The Bishop of Autun.

"To Sir John Riggs Miller, Bart.,
Member of the House of Commons, London."

racy, it is only fair to expect the same degree of accuracy in the pendulum. Now the opponents of the metre plead, that more recent measurements of the earth would require it to be $\frac{856}{1000000}$ths, or nearly the tenth part of a millimetre longer than it is.* Has the accuracy of the pendulum been subjected to so severe a test? Is it possible to pursue the search in such a way as to arrive at a degree of exactness equalling that which is thus demanded from the advocates of the metre? Certainly, I apprehend, that no such exactness has yet been obtained. In support of this opinion I will quote the authority of those, who have been engaged in the experiments, and of others intimately acquainted with the subject.

Captain Kater himself, after finishing the long and laborious series of experiments, entrusted to him in pursuance of the above Resolution of the House of Commons, arrives at the following conclusion:

"It must be evident that nothing very decisive respecting the general ellipticity of the meridian can be deduced from the present experiments. For this purpose it is requisite that the extreme stations should comprise an arc of sufficient length to render the effect of irregular attraction insensible; and this effect might be diminished, if not wholly prevented, by selecting stations of similar geological character, and which should differ as little as possible in elevation above the level of the sea."†

"On the whole," says Sir David Brewster, "it is sufficiently obvious, that no formula can be obtained to represent, with perfect rigour, the lengths of the pendulum over the globe; and that the local variations in the density of the strata, which compose the crust of the earth, prevent us from determining the true nature of the meridional curves." He also observes, that "the relative density of the earth at different places may be properly determined by the mea-

* Other measurements, subsequent to that by Méchain and Delambre, will be mentioned in the next Section.

† Phil. Trans. for 1819, p. 425.

surement of the pendulum; but it is unsafe to reverse the process, and assign the length of the pendulum from the assumed density of the earth."*

General Sabine's book, which at least in England must be regarded as the standard work on the subject, speaks in similar terms of the effects of variations in density.†

A new difficulty is presented by Mr. Gilbert in the following passage:

"It having been shewn by Sir Isaac Newton that a resisting medium does not affect the time of vibration, and Kater having applied the principle of convertibility between the axis of suspension and a parallel line passing through the centre of oscillation, I really expected the most accurate results. With a given length, the time is as the square root of inertia directly, and as the square root of gravity inversely; and inertia being supposed constant, the correction for buoyancy was quite obvious; but now it seems that inertia is variable, in consequence of air adhering to a body in motion, and probably differing in quantity for different materials and for different degrees of smoothness."‡

The eight Commissioners appointed as above mentioned (p. 1) to consider the steps to be taken for restoring the standards of Weight and Measure, in their Report published in 1841 (p. 6), object to the method of restoration prescribed by the Weights and Measures Act, which was to restore the yard by making it "bear a certain proportion to the length of the

* Edinburgh Encyclopædia, 1823, Art. PENDULUM, pp. 361, 364.

† "Account of Experiments to determine the Figure of the Earth," Lond. 1825. See also Parry's "Voyage in the Hecla and Griper," Appendix, p. 164.

‡ "Report on the Restoration of Standards," 1841, p. 27. In the Cambridge Phil. Trans., Vol. IX. pp. 8—106, Professor Stokes pursues the inquiry respecting the obstruction to the free motion of a pendulum by the air, which becomes attached to it. He refers to experiments and observations on the same subject by Baily, Bessel, Challis, Coulomb, Dubuat, Green, Plana, Poisson, and Sabine.

pendulum, vibrating seconds of mean time, in the latitude of London, in a vacuum, at the level of the sea;" and in support of their opinion they quote the authority of Dr. Thomas Young; of Bessel, the Astronomer Royal of Prussia; of Mr. Francis Baily, who was one of their own number; and of Captain Kater, who had himself conducted the experiments, to shew that these experiments, notwithstanding the great care bestowed upon them, were chargeable with various errors and uncertainties. One of these eight Commissioners, the Very Rev. Dr. Peacock, has on another occasion stated the same objections more fully. The following are his words:

"Since the passing of the said Act, the progress of scientific inquiry had shewn, that nearly all the theoretical corrections, which Captain Kater had applied to the reduction of his observations, were imperfect or erroneous. Bessel had shewn, that the formula used for the reduction to a vacuum was very defective; and Colonel Sabine had established the same fact by very decisive experiments; Dr. Young had not only shewn, that the reduction to the level of the sea was erroneous, but also that it might be materially affected by local circumstances (*Works*, Vol. II. p. 99); and Colonel Sabine had given reason for thinking that such circumstances, whether geological or otherwise, were not obscurely indicated in the neighbourhood where the pendulum was swung; and Mr. Baily, who repeated and varied all the observations with his usual perseverance and skill, discovered other anomalies and possible sources of error, which threw additional doubts upon the perfect accuracy of this and similar determinations."*

Besides the sources of error referred to by Dr. Peacock in this extract, I have alluded to another, which must, as it appears to me, be taken into account, though hitherto entirely overlooked. I mean the determination of the pendulum to preserve its own motion in conformity with Newton's first law, the law of the

* "Life of Thomas Young, M.D., F.R.S.," by G. Peacock, D.D., London, 1855, pp. 350—355.

inertia of matter. In the accounts of the experiments, we are informed, that it was found difficult to keep the knife edges of the convertible pendulum in one position upon the agate plates, by which they were supported. Is it not probable that this difficulty arose, not from the want of perfect horizontality in the agate plates, but from the constant effort of the pendulum to adhere to its own plane of vibration, instead of conforming to the plane of the rotation of the earth? This tendency can only be obviated by repeating the experiment where the plane of the vibration of a pendulum swinging east and west will coincide with the plane of the earth's rotation; and thus we are brought by a totally different path to the very same conclusion, which La Condamine adopted as the guide of his experiments,* and which he recorded on the model deposited by him in Quito, presenting a delineation of the length of the pendulum as ascertained by himself under the Equator, and inscribed with the words commemorative of his ardour in the pursuit of a great and good object,

MENSURÆ NATURALIS EXEMPLAR, UTINAM ET UNIVERSALIS.†

The various considerations, which I have now mentioned, leave no doubt in my own mind, that, at least under present circumstances, there is no sufficient reason to take the second's pendulum as the unit of length in preference to the metre; and I am thus brought to the discussion of the fifth Question, which relates to its accuracy.

* See above, p. 16.

† Dove, "Maass u. Messen," p. 9.

V. Is the alleged want of accuracy in the Metre a valid objection to its universal adoption?

The accuracy of the metre has been impugned on five different grounds.

1. In the first place, it is alleged, that the observers neglected to take into account the convergence of the meridians. This charge appears to have originated, or at least to have been first propagated, in this country by the Editors of the Penny Cyclopædia. See Vol. XXV., London, 1843, Art. Trigonometrical Survey, p. 216. The passage is quoted by Mr. Robert Slater in his "Inquiry into the Principles involved in the Decimalization of the Weights, Measures, and Moneys of the United Kingdom," London, 1855, pp. 3, 4.

A ready answer to this charge is found on examining dates. The metre was adopted by the legislative body of France, and deposited in the national archives, where it still remains, on the 22nd of June, 1799.* It was deduced from the measurement of the arc of the meridian lying between the latitudes of Dunkirk and the fort of Mont-Jouy, near Barcelona, which measurement had been executed for the purpose by Méchain and Delambre.† A few years afterwards, the completion of another measurement was entrusted

* "Base du Système Métrique," Tom. I., Paris, 1806, p. 95.

† The reasons assigned by the Commissioners for the choice of this arc are,

1. Its extent, being more than $9\frac{1}{2}$ deg.;

2. Its position partly to the north and partly to the south of the mean parallel of north latitude, 45 deg., admitting of a good comparison with the indications of the pendulum;

3. The circumstance of its two extremities being at the level of the sea. "Base du Système Mét.," I. p. 17.

to Biot and Arago; viz., that of the arc between the latitudes of Barcelona and Formentera. It is alleged that these celebrated men computed the distance "without applying the proper correction of meridians." It is evident that this error does not affect the present question. The metre had been already determined, having been deduced from a previous measurement.*

2. The second objection is also refuted by an examination of dates. It is alleged that the metre is only provisional.† The facts are as follows.

The legislative body of France, having decided upon adopting as the unit of length a bar of platinum (une régle de platine) intended to represent the 10,000,000th part of a quadrant of the meridian, measured from the North Pole to the Equator, and that all linear measures should be deduced from it by decimal multiplication and division, further determined in the year 1795, to assume a certain measurement provisionally, in order that the system might be introduced into practice as soon as possible. The measurement of the earth so assumed was that by Lacaille, executed A.D. 1744. The metre deduced from it was declared to be

* The final deduction, A.D. 1799, from Méchain and Delambre's measurement is given in the "Base du Système Métrique," I. p. 94, viz. that the quadrant of the meridian is 5130740 toises, and the metre 443.295936 lines. The discussion, in which Puissant maintains that the estimate made by Biot and Arago of the distance between Mont-Jouy and Formentera was too small, will be found in the Comptes Rendus for 1836.

† These often-repeated objections have been brought forward very lately in a note to a valuable and carefully written Report, presented to the Wirral Agricultural Improvement Society by the Committee of that Society on Weights and Measures. "Your Committee," say they, "are informed, that the distance in question (viz. from the North Pole to the Equator) has not yet been satisfactorily determined; and that the measure of length, which forms the basis of the French Metrical System, is in fact only a *provisional* representation of what it is usually stated to be, differing from the result of the most recent calculations."

the *mètre provisoire*, and became for a time the basis of the Metrical System. The attempt to measure the earth with still greater accuracy was then prosecuted by Méchain and Delambre, and the result was the solemn recognition by the Legislature, on the 22nd of June, 1799, as already stated, of a new metre as the *mètre définitif*. This is a bar of platinum preserved in the *Hotel des Archives* at Paris, the provisional metre being preserved in the *Conservatoire des Arts et Métiers*. The latter is only important as a memorial of the labour and care employed in the construction of the Metrical System. The former is that which is always meant, when any one speaks simply of THE METRE, and all metres of every material, with their multiples and subdivisions, as used not only throughout France, but in every portion of the globe, are copied from this original. The law which established it definitively, ordained the publication of a medal with a motto, '*A tous les temps, à tous les peuples.*'*

To this day it has undergone no change by any legislative enactment. It maintained its place, even whilst the other parts of the Metrical System were abandoned for the *Système Usuel;* and, if at any future time the French nation in conjunction with others, which adopt it as their unit of length, shall come to the conclusion, that it is not perfectly accurate, it is probable that the correction, if any, will be applied, not by altering the length of the metre itself, but by declaring that it shall be measured at a different temperature, instead of the temperature of melting ice.†

* Tarbé, "Manuel des Poids et Mesures," Paris, 1845, p. 378.

† I cannot find that this temperature is fixed by any positive law, although it was applied, under the authority of the Commissioners, in constructing the Definitive Metre of 1799, and has been maintained to this day. It

3. In the third place, the accuracy of the metre is confidently impugned, because Méchain expressed a doubt about the correctness of his own estimate of the latitude of Mont-Jouy, a fort near Barcelona, at the southern extremity of the great triangulation, which was the basis of the measurement.

This accusation is accompanied by the intimation, that Méchain was chargeable in this affair with disingenuous concealment. I doubt whether there is any reason to cast such a reflection upon the memory of a philosopher, whose devotedness to the great and very difficult task, which he had undertaken, appears entitled to the commendation of all posterity. After his death in 1805, and for some time previously, his papers were in the hands of his colleague Delambre, whose account of the affair at the commencement of the second volume of the *Base du Système Métrique* (Par. 1807), followed by an ample and most scrupulous discussion of the question,* seems to me perfectly clear and candid. We are informed that after the termination of his labours on the measurement of the arc, Méchain was detained as a prisoner in Barcelona. He employed his leisure in ascertaining the latitude of that city, and thus he calculated a second time the latitude of Mont-Jouy, and found a difference of 3″ 24 from the latitude of the same place as formerly calculated by himself. This difference was so considerable as to give him no small perplexity and embar-

appears that the temperature may be altered, whenever any sufficient reason for the change is made manifest, and that the Metrical System is in this respect self-adjusting. See Base du Système, III. 642.

* Pp. 587, 616—631. Those who are disposed to examine this intricate question, should consult the very interesting Memoir by Nicollet in the "Connaissances des Temps" for 1831.

rassment, because it led him to doubt the exactness of his former observations. It was impossible to decide whether the discordance was to be ascribed to some defect in his previous operations, or to some local cause affecting the recent indications of his instruments. Delambre, with the concurrence of his co-commissioners, decided, after much deliberation, on retaining Méchain's calculation as originally determined. He repeatedly and in the strongest terms expresses his conviction of the accuracy of his colleague's observations both at Barcelona and at Mont-Jouy. He concludes, as the most probable source of the apparent error, that the indications of the instrument were affected by the varying density of the strata under the two places of observation, and he states (p. 619), that the discrepancy was even less than that found in England by Colonel Mudge, and attributed by him to similar causes.

Mr. Airy, the Astronomer Royal of England, also discusses this question in his able treatise on the Figure of the Earth.* He supposes the discrepancy to have arisen from the imperfection of the Repeating Circle as an instrument of observation. At the same time he on the whole confirms the original conclusions of Méchain and Delambre respecting the latitude of Mont-Jouy, inasmuch as they had made it 41° 21′ 44″ 90;† and Mr. Airy, adopting the conclusion of M. Nicollet, makes it 41° 21′ 44″ 535, the difference being less than half a second.

4. The next objection to the accuracy of the metre, which I shall consider, is that most commonly urged, viz., that it is not a 10,000,000th part of the quadrant

* "Encyclopædia Metropolitana," Vol. V., A.D. 1845, p. 202.

† "Base du Système Métrique," II. p. 563.

of a meridian, inasmuch as it differs from the results of more recent calculations.

The fact appears to be, that in the process of measuring the earth, no less than in experiments with the pendulum, absolute accuracy is unattainable; but that the metre is sufficiently accurate for all practical purposes, and as truly an ascertained aliquot part of the meridional quadrant as any other measure that has been, or can, at least under present circumstances, be proposed.

The authors of the Metrical System never hoped or pretended to arrive at perfect exactness in the measure of the earth. They knew that no measurement whatsoever can be mathematically accurate, such accuracy being expressed only by imaginary, not real lines. Their endeavour was, by the use of the best instruments, by repeating their observations, by taking every precaution for the avoidance of error, and by making all the corrections, which were proved to be important, to come as near as possible to a true result.* No one

* The first sentence in the great work, which describes and records their labours, the "Base du Système Métrique," is as follows:

"Les deux questions de la grandeur et de la figure de la terre, qui exercent depuis si long-temps les astronomes et les géomètres, paroissent de nature à n'être jamais entièrement épuisées."

The following passages also indicate their sense of liability to error: Vol. II. pp. 260—272, 292, 294; but above all, Delambre's investigation on the obscure case of Méchain, already mentioned.

Their successor, M. Biot, alleges as a ground of satisfaction, that the mean radius of the earth may be ascertained to within about 200 metres or to about one part in 30,000. But he professes no more minute accuracy than this. Biot et Arago, "Receuil d'Observations Géodésiques," Paris, 1821, Introduction.

Delambre wished to have the value of the metre stated at 443.3 lines, rather than 443.295936 (see above, p. 25, note), because he thought six places of decimals too great a number. Saigey, "Traité de Metrologie," Par. 1834, p. 132. Base, III. 103. Indeed, in the third volume of the "Base du Système Métrique" (pp. 5, 135, 138), he increases the correct

has denied that their exertions, marked, as they were, by energy, perseverance, and self-sacrifice, no less than by ability of the highest order, have entitled them to the admiration and gratitude of all enlightened men. Since the completion of their labour, the measurement of meridional arcs has been undertaken by other parties, and of necessity with a slight difference in the results. The improvements suggested by experience, and by the advance of science, have been carefully introduced. In former instances, prior to Méchain and Delambre's measurement, an angle was thought to be sufficiently defined by a church tower or a pile of stones; more recently a mirror, or a painted circle of wood, has been fixed on the summit of the previous object, and, if large enough to be distinguished at the assigned distance, it has admitted of greater nicety in the observations. On such grounds, philosophers are naturally disposed to prefer the more modern conclusions; and the consequence is that, if the metre were now to be determined, it would probably be made larger than the established metre by a quantity, which, though not obvious to the eye, may nevertheless be rendered perceptible by the use of very delicate instruments, and which, though quite insignificant as far as regards the daily operations of commerce and even the ordinary pursuits of science, may become considerable by being multiplied, and may consequently have a sensible influence on geodetical and astronomical inquiries.

All those who have taken a part in these operations,

value of the metre, i.e. of the 10,000,000th part of the quadrant as deduced from his own and Méchain's triangulations, to 443.328 lines; but he again (p. 297) reduces it to the former value in consequence of fresh information received from Biot. Schmidt afterwards made it 443.29977 lines. Astron. Nachrichten, A.D. 1831, p. 371.

both the earlier observers and those who have followed and endeavoured to surpass them, profess to reduce their measurements to the level of the sea, or "the surface of the ocean," and hence to calculate the circumference of the earth at that level. Nevertheless, I cannot find that any one of them defines what he means by "the level of the sea."* This level is disturbed by a variety of causes. It changes continually with winds, currents, tides; it is probably subject to alteration from the height of the land in its vicinity and from the form of the neighbouring shores, from the perpendicular pressure of the air above and the unequal attractions of the strata beneath. Bessel referred his arc to the Baltic; Swanberg to the Arctic Sea; Lambton and Everest to the opposite shores of India; whilst the vast Russian survey connects the Euxine with the Polar Sea, and the calculations of Méchain and Delambre suppose their arc to coincide with the level of the German Ocean and the Mediterranean Sea. The English authors, with some others, have given their hypsometric measurements in feet, thus apparently professing to assign the height of each point of their triangulation *within one foot* of the level of the sea, although this level varies at different times and in different places not by one foot only, but by 50 or perhaps 100 feet, and possibly to a greater extent. Those who are so vague in their expressions and assume such a fluctuating datum for their hypsometry, ought

* Of course this does not apply to the very able staff of officers, who are now employed by the English Government on the Ordnance Survey, and who understand by "the level of the sea" the mean between high and low water. In the great Indian survey, Lieut.-Colonel Lambton calculated one of his bases "*above the low-water mark.*" Phil. Trans. for 1818, p. 489. But even this degree of precision is very rare. Colonel Mudge also refers to *low-water mark.*

not to impugn the metre by pretending to a degree of precision, to which Méchain and Delambre never did pretend.

It is remarkable, that there is not only a want of agreement on comparing the various measurements of the earth with one another, but that discrepancies of equal comparative amount are commonly found on comparing together the successive portions of the very same measurement. An unexpected irregularity was discovered by Colonel Mudge in the line which he measured from the Isle of Wight to Clifton, near Doncaster, and was ascribed to the powerful attraction of the mass of granite at Mount Sorrel, in Leicestershire. It was a similar discordance, so far as we are able to judge, that distressed and perplexed Méchain at Barcelona.* Both in England and in France it was found that the degrees, instead of decreasing constantly in going from the north to the south, appeared to decrease very irregularly, and sometimes even to increase.† Major Lambton met with the same anomalies in his Indian measurements. In one instance he conjectured that the discordance was produced by a bed of iron ore. His reviewer, Playfair, remarks—"Some part of this irregularity, but certainly a very small one, may be ascribed to error of observation; the greatest part must, we think, be placed to account of the irregularities in the direction of gravity, arising from the irregularities at the surface or in the interior of the earth, the attraction of mountains, for example, or the local variations of density in the parts immediately under the surface."‡ The following paragraph in the same article (p. 325) appears very apposite to the present question:

* See above, p. 27. † Playfair, in Ed. Rev. IX. p. 390.

‡ Ed. Rev. XXI. pp. 322, 323. Works, IV. p. 408.

"The anomalies which have occurred in the measures of degrees, and of which the appearances seem to increase in proportion as greater pains are taken to avoid inaccuracy, have naturally drawn the attention of mathematicians, and the question, what part of them is to be ascribed to error, and what to irregularities in the structure of the globe, has come, of course, to be considered. That a small part of them only can be ascribed to the former cause, is rendered probable by the very circumstances just stated, that they are not diminished, nay, that they even seem to be increased, by the care to avoid error. It seems clear from that consideration, that the irregularities are in the object sought for, and are only brought more in sight by more microscopical observation, by the excellence of the instruments, the accuracy of the computations, and the extent of the line measured. No measurement was ever executed with greater care than that in France;* and the great extent of the arch measured, as well as the ability and skill of the observers, make the mean result, the length of the degree in the parallel of 45 deg., the datum most perfectly ascertained of any that regards the figure of the earth. Yet, even here, we find in the detail, that there are great anomalies, and that the successive degrees increase with much irregularity."

The measurement of the earth is a task, which requires not merely the use of the best instruments and the highest amount of ability, diligence and perseverance, but also superior moral qualifications, to wit, truthfulness and integrity. The operations are generally conducted in solitude and privacy, the observer being accountable to no one besides his own conscience for the faithful discharge of his undertaking, whilst innumerable hardships, disappointments, and difficulties, tempt him to the betrayal of his trust. Of this an exemplification is afforded in the next survey, which I shall mention, viz., that made in continuation of Colonel Lambton's and conducted by Lieutenant-Colonel Everest. His account appears to me the more valuable, instructive, and trustworthy, because he shews the greatest possible degree of candour and openness

* This was written in 1813.

in the detail of his misfortunes. For a long time he conducted his operations "with death staring him in the face," his body always lowered by two men into his seat at the zenith-sector, and raised again out of it in the same way, and his limbs supported to enable him to use his theodolite.* This instrument had been shattered like its owner. In the year 1808, under the management of Lambton, it fell with a violent crash against the side of a pagoda, and, though skilfully repaired, could never afterwards be free from some defects.† The following extracts from Everest's work may assist the reader in judging what reliance ought in general to be placed on these geodetical results.

After describing a remarkable case of disturbance from the vicinity of a mountain chain, he thus proceeds:

"Who shall say what parts of the globe can be free from such sources of irregularity in the direction of gravity? Even upon the sea this hidden influence may take effect; but in such places as are manifestly near to a great domineering mountain, there is a palpable cause for rejecting at once results, which would lead to conclusions irreconcilable with the ordinary laws of gravity. Considering, therefore (though the earth is, generally speaking, an ellipsoid of revolution on the minor axis) that the direction of gravity in hardly any part of its surface strictly coincides with the normal, I should say that every place has two latitudes and longitudes, the one being that belonging to the assumed ellipsoid computed for geographical purposes, the other that derived from celestial observations."‡

* "Account of the Measurement of an Arc of the Meridian between the Parallels of 18° 3′ and 24° 7′," London, 1830, 4to, p. 37.

† Ibid. p. 46.

‡ Ibid. p. 108.

At the meeting of the British Association for the Advancement of Science in Dublin, August, 1857, Professor Hennessy read a memoir "on the Direction of Gravity at the Earth's Surface." The conclusions, at which he arrives on purely theoretical grounds, are in full conformity with those derived from observation by Colonel Everest and others.

Again,

"The observed angles of almost every triangle are affected with certain small errors, which arise partly from want of skill in the observer, partly from want of the signals being properly placed over the centres of the stations, partly from defects in the instruments employed, and partly from lateral refraction."*

Of the difficulties produced by attacks of fever, the mutinous and disorderly behaviour of servants, the failure of provisions, the absence of ordinary comforts, and the intervention of deep rivers and lofty ranges of impassable mountains with trackless forests and jungles, abounding with all kinds of poisonous insects, reptiles, and ravenous quadrupeds, it is impossible to form a conception without reading Everest's own narrative.

With the great and memorable Indian survey may be contrasted that of Prussia. The sapphires at the two extremities of Bessel's standard† are fit emblems of the comparative luxury of the process, from which it was derived; and, if we consider that this survey extended over a plain bordering on the Baltic Sea, and that it was conducted subsequently to all those already mentioned, in a period of tranquillity and peace, and amid the cheering aspects of high civilization and social culture, we may perhaps infer that it was less liable to error than any other, and that the compara-

* Ibid. p. 74.

† See above, p. 12, and Bessel, "Gradmessung in Ost-Preussen und ihre Verbindung mit Preussischen und Russischen Dreieecksketten," Berlin, 1838, 4to. See also Bessel's "Populäre Vorlesungen" (published after his death by Schumacher), Hamburg, 1848, pp. 269—311. He gives it as the result of his calculations, that the length of the quadrant, which we must now regard as the most probable, instead of being 10,000,000 metres, is 10,000,565 metres, and that, to make the length of the quadrant agree with 10,000,000 metres, the metre must be lengthened by the 40th part of a line. This may be compared with Delambre's determination, as mentioned above, p. 25, note.

tively small arc which it established, might be safely assumed as a portion of a real terrestrial meridian, if only there were sufficient proof of the regularity of the earth's figure.

It is admitted beyond dispute, that a great increase of density in any one region of the earth will produce a permanent elevation of the ocean over that region. This seems to be the only assignable cause of the great excess of water in the hemisphere, of which New Zealand may be regarded as the centre. On this supposition we may conclude, that if the denser submerged strata there began to expand through the operation of physical causes, the supernatant waters would be driven northward, and would overflow the immense tracts of dry land surrounding Great Britain and the North Pole, so that the terraqueous globe would present the same aspect here, which is now exhibited around New Zealand. Another consequence of the supposed higher specific gravity of the New Zealand hemisphere will be, that the water will overflow it in such superabundance as to rise to a greater distance from the centre of gravity than the water on the opposite side. In other words, the greater attraction of the dense strata will, in consequence of the levity of water compared with earth, and the necessity that the centre of gravity of the whole resulting mass should coincide with the centre of gravity of its earthy portion, raise the sea-level considerably higher around New Zealand than it is on the shores of Europe. Such a state of things must, I apprehend, affect the general configuration of the terraqueous globe, making it slightly and irregularly pyriform rather than accurately ellipsoidal, and producing a permanent irregularity in its figure far greater in every respect than those, which

have hitherto been taken into account by geodetical surveyors.

The inference from all the preceding facts and considerations is, that neither the metre nor any other linear measure, which may be substituted in place of the metre, can with our present means of information be assumed with certainty, and to the exclusion of all other quantities, as the exact 10,000,000th part of the quadrant of a meridian supposed to be measured from the North Pole to the Equator. All such quantities must be taken as approximations, the same latitude being used in regard to them as in all ordinary cases of linear measurement: for it is to be observed that minute differences must exist in all attempts to compare the lengths of different objects. Euclid's axiom, "Things, which are equal to the same, are equal to one another," is strictly true only of mathematical lines and other imaginary quantities. In practice it is sufficient, if the inequality is not obvious to the naked eye, and does not go beyond reasonable limits. All parties can only make it their honest aim to arrive at perfect exactness, but will not pretend to have attained to it, such a pretension being the proof of nothing but their own ignorance.

If we pursue the accusation against the metre to its practical consequences, we shall find them either very serious, or very ridiculous. Let us place ourselves in a draper's shop at Paris. A hundred attendants are behind the counters with metres suspended before them from the ceiling, and used in measuring what they sell. A thousand sales are effected in a day, and thus a thousand frauds are committed, because it is plain, that the quantities of ribbon, tape, cloth, and other materials sold, will either exceed or fall short

of their professed length, compared with the circumference of the globe, by the thickness of a sheet of paper. Or, let us imagine the case of a landed estate. Mr. Galloway, the last author of celebrity on this subject,* on the authority of Schmidt,† and pursuing the same track with Dove,‡ Airy,§ and the Penny Cyclopædia,‖ has given us the results of twenty different measurements between the Equator and 66 deg. of North latitude.¶ Suppose Mr. Galloway were to employ twenty of our cleverest land-agents to measure an estate. The results would infallibly differ, probably as much in proportion as the metre differs from those measurements, which are brought forward as preferable to it. Suppose now, that the expected purchaser of

* Article FIGURE OF THE EARTH, in Encyclop. Britt., 8th ed., Vol. IX. p. 563.

† Schumacher's "Astrom. Nachrichten," 9, 371, No. 213. See above, p. 30.

‡ "Maass und Messen," Berlin, 1835, pp. 12, 13.

§ Article FIGURE OF THE EARTH, in Encyclop. Metropol., London, 1845, p. 172.

‖ Article TRIGONOMETRICAL SURVEY, pp. 216, 225.

¶ One of these 20 measurements was that executed in India by Lambton, as already mentioned, pp. 31, 32. It is to be observed, that, according to this officer, the metre is too long, not too short; but the difference is such, that, whether *plus* or *minus*, it is in his opinion utterly insignificant. The following are his words, after calculating 21,869,976 fathoms as the elliptic meridian of the earth: "— which, divided by 4, gives 5,467,494 fathoms for the quadrantal arc of that meridian; and this, reduced into inches, and divided by 10,000,000, will give 39.366 inches for the French mètre, at the temperature of 62 deg. Now, the metre deduced from the measurements of Delambre and Méchain, and reduced from 32 deg. to 62 deg., was 39.371 English inches, which exceeds this one by .005 inches, a quantity too small to affect any standard measure; so that the metre, as deduced from a comparison of all the recent operations, may be considered, as to practical purposes, the same as that which has been adopted by the French mathematicians, being obtained from comparing the measurements of Delambre and Méchain with those of Bouguer and Condamine."—Phil. Trans. for 1818, p. 514.

the estate were on this ground to break off from his engagement. He would be called a rogue and his argument a quibble.

The objection to the metre on the ground of inaccuracy may at least be called a *refinement.* If so, I may be permitted to go on refining, and to inquire more particularly what is implied in the assertion, that the metre is the 10,000,000th part of the quadrant from the North Pole to the Equator? To form a distinct idea of this proposition, we must suppose the centre of gravity of the earth to be the centre of an elliptic spheroid, and that the portion of any ellipse, coinciding with it and passing from the North Pole to the Equator, is so divided into 10,000,000 arcs, that the chord of each arc equals the metre in length. The supporters of the metre assume that this curve coincides somewhere, or in a general sense, with the surface of the earth between the North Pole and the Equator, to which hemisphere the observations have been confined, so far as they concern this question. The opponents of the metre deny this assumption; they say, that the imaginary curve agreeing with the metre is everywhere under the surface of the earth; and they allege, that to conform to the required condition, and to agree with a true meridional arc, the ellipse and the metre which is an aliquot part of it, ought to be larger. I do not think that this assertion can at present be established. We know, that the earth's figure presents numerous and extensive inequalities. We know also, that its ellipticity is quite undetermined, the calculations ranging between 285* and 334.† Whilst, therefore, I believe, that the metre

* Capt. Basil Hall in Phil. Trans. for 1823, p. 240.

† "Base du Système Métrique," I. 94.

cannot be assumed to be *certainly and solely, and to the exclusion of even the minutest variation*, the 10,000,000th part of the quadrantal arc, I cannot help suspecting, that the same objection applies to every measurement hitherto attempted, and indeed that the problem of an absolutely exact measurement of our planet never will be solved; and whilst I consider the question as open to discussion, and would not discourage any attempts at improvement, I am disposed to think that the same bar of platinum, which has continued unchanged by legislative enactment for nearly sixty years amidst all the changes of ocean and of earth, ought to retain its original rank as the proposed unit of length for all nations. I will only add, that should it unhappily be destroyed by an accident similar to the fire at Westminster in 1834, it may without any difficulty be restored, not by a new measurement of a meridian, but by a reference to some of the many accurate and authentic copies of it, which are displayed in all civilized countries.

It must not be forgotten, that in case the rectification of the metre should be rendered expedient by the progress of discovery, the founders of the Metrical System themselves provided a remedy, not by altering the metre itself, but by a change in the regulation, which fixes its standard temperature.* This temperature is now fixed at zero of the centigrade scale, which is the temperature of melting ice. The consequence is, that in daily use the rectification takes place without any legislation at all. The warmth of the hand, the heat of the atmosphere, or the superior temperature of most foreign countries, will of themselves prolong the metre so as to meet the objection of those who deny its accu-

* See above, p. 26, note.

racy.* It is only in rigorously scientific calculations that the incorrectness of the metre, even supposing it proved, can be of the slightest importance.

Having found occasion to dwell at so great length on the differences in the results of the best astronomical investigations into the size and figure of the earth, I wish to counteract an impression which may be apt to force itself upon the mind of the reader, viz., that the subject is one of so great uncertainty, that none of the conclusions are to be trusted. I am convinced that we ought to draw the very opposite conclusion. The differences, which are the subject of so much controversy, are extremely minute. They prove, not that

* The amount of the prolongation will of course depend on the *material* of the metre as well as other circumstances. If it be of brass, an increase of temperature equal to 1 deg. Fahrenheit above that of melting ice will make it long enough to answer the objection to its inaccuracy, since Captain Kater found that a brass bar expands as nearly as possible to the amount of one part in 100,000 for every degree of Fahrenheit.—Phil. Trans. for 1818, p. 61 and p. 109, and for 1819, p. 343. The expansion of platinum is half that of brass.—Graham's "Elements of Chemistry," p. 2. Wood scarcely expands at all.

The following observations of M. Saigey appear to me to contain much good sense, and to be well deserving of attention:

"Delambre a fait tout ce qu'il a pu pour atténuer les erreurs de la commission du mètre; et il est assez singulier de voir l'écrivain chargé de rédiger les travaux faits à l'occasion du Système Métrique corriger des résultats réputés irrévocables par la loi, et substituer d'autres nombres à ceux qui devaient représenter à tout jamais les dimensions de notre globe. L'étalon du mètre restera, si l'on veut; mais, au lieu de le prendre à la glace fondante, il faudra désormais le considérer à une température plus élevée. Telle est du moins l'opinion de Delambre, qui avoit d'abord fixé cette température à 8 degrés et demi; mais elle eût deja subi plusieurs variations, si, à chaque nouvelle operation géodésique, on eût calculé la valeur qui en resultait pour le mètre. On devra donc bien se garder d'introduire dans la loi toutes ces fluctuations, qui n'intéressent que les savans et nuiraient plutôt à la propagation du Système Métrique. Le point capital et pressant est l'abolition des anciens systèmes de poids et mesures. Dans quelques siècles, alors qu'on aura recouvert les continents d'un immense réseau de triangles, il sera permis d'assigner la valeur du mètre, non pas avec neuf chiffres, ce qui est une niaiserie de géomètre, mais avec cinq chiffres bien consolidés."—Traité de Métrologie, Paris, 1834, p. 133.

the observers are unworthy of our confidence, but rather that the delicacy of their instruments, their accurate attention to the smallest details, and their faithfulness in recording everything as it occurs, entitle them to be trusted so far as it is possible to rely upon the report of human beings, who are at all times liable to casualties and to errors. Our Astronomer Royal, Mr. Airy, concludes his account of the differences in the calculation of the earth's ellipticity by saying:

"Instead of being surprised that such a difference exists, we may well be astonished at the accuracy of modern measures of all kinds, which make so small a quantity a subject of controversy."*

If this remark be just in regard to numbers, which differ from one another by a very small quantity, which, however, admits of computation, how much more is it applicable to the question respecting the accuracy of the metre, which differs from the length proposed to be substituted for it by a quantity still more minute!

The observations, next quoted, are from the pen of a philosopher, than whom no one is better entitled to the most reverential attention and confidence. They follow his account of certain discrepancies in the results of Colonel Mudge's survey in the South of England:

"Though we have no doubt that irregularities, which are at present so difficult to be accounted for, will, by the prosecution of the subject, become perfectly explained, we confess that we have felt some disappointment on reflecting that hitherto the more that has been done to ascertain the figure of the earth by the measurement of degrees, the less satisfactory in some respects has our knowledge of it become. The more microscopically we have observed, the more irregularities we have discovered; and in the last experiment, which may justly be reckoned the best, what is accounted the natural order of things has been almost completely inverted. All this, however, is only a

* On the FIGURE OF THE EARTH, in Encyclop. Metrop., London, 1845, p. 231.

motive for continuing the research, which, if prosecuted with skill and perseverance, must ultimately lead to the knowledge of the truth."*

In fine, if we imagine a canal to be cut from the Equator to the North Pole and filled with fluid at the general level of the ocean, it is certainly possible, perhaps even probable, that on measuring it with the metre we should find its length to exceed ten million metres by an amount not less than a furlong. It is equally certain, that none of the measurements, which lead to this conclusion, are in perfect accordance with one another. But this ought not to cause distrust. The fact is, that the more careful and conscientious is the observer, and the more delicate are his instruments, the greater is the chance of the development of minute and irreconcilable discrepancies in the results of his calculations. But such discrepancies, instead of shaking our confidence, are rather adapted to inspire admiration of the approach to perfect exactness, which is rendered attainable by the progress of scientific research.

5. The fifth and last objection to the metre relates to its workmanship and preservation.

After the length of the 10,000,000th part of the meridional quadrant had been calculated in terms of the Toise of Peru by Van Swinden on behalf of the other Commissioners,† the bar of platinum, intended to represent that length in an exact, permanent, and visible form, was made by an artist of the highest reputation, exhibited on the 22nd of June, 1799, before the Corps Legislatif, and deposited the same day under the security of four keys in the National Archives.

Notwithstanding these formal and sedulous provi-

* Professor Playfair in Ed. Rev., Vol. V. p. 390. Works, Vol. IV. p. 217.

† See above, p. 25, and Base du Système Métrique, Tom. III. pp. 415—433.

sions, "the pride of philosophy," to borrow the language of a highly distinguished opponent of the metre, "was destined to encounter another rebuke." In the year 1837, an eminent Professor of the University of Munich, Dr. Steinheil, was in Paris, and had occasion to pay particular attention to the prototype in order to obtain an accurate copy. He observed on its extremities not only file-marks, but small depressions made by comparing instruments.*

It appears to me, that there must have been culpable negligence on the part of those who, being admitted to compare the copies, injured the original. I cannot, however, see that these defects or injuries are by any means sufficient to make the metre useless. Although the file-marks were deep enough to be called scratches, or even channels, it is evident that the length of the metre is to be taken from the general surface of the instrument, not from the bottom of these scratches; and, if depressions have been made by carelessness in comparing, these did not exist in the instrument as seen and adopted by the Legislature, and consequently the inequalities, which they produce, are not to be taken into account; but the original axis of the bar, measured from end to end, must still be regarded as the real metre.

Nor should it be forgotten, that, whatever injuries may have befallen the metre in the last sixty years, or may befall it in time to come, its true length may always be ascertained within a quantity infinitesimally small through the medium of the authorized copies, which are either preserved in France, or dispersed among all other civilized countries. Moreover, if ever it shall be made apparent, that there is sufficient reason

* Abhandlungen der Baierischen Acadamie, Band IV. s. 251.

to substitute a new metre instead of this original, in order to remove the objection now explained, it seems agreeable to the spirit and intention of the original law, that this should be done.

The following remarks by Professor Playfair form the conclusion of his review of the *Base du Système Métrique.** They were written in 1807; and, if they were deserving of attention when we were at war with France, with how much more of hope and sympathy may they be received when we are so much better prepared, not only to admire the science, skill, and perseverance of the French astronomers, but to acknowledge the enlightened generosity, with which they have uniformly aided the advance of this sublime project for the good of the whole human race.

* See above, p. 9, note, and Playfair's Works, IV. 257.

In the 3rd volume of the Base du Système Métrique, Paris, 1810, pp. 301—309, is a reply to this most excellent article by Delambre himself. He regarded it as the only article on the subject of the metre, which had yet appeared, and which was deserving of attention. It is instructive and delightful to find the question discussed amicably and rationally, as it is in this instance, by two first-rate mathematicians on the opposite sides of the British Channel. Among other objections to the Metrical System, Playfair had referred to the alleged superior advantages of the duodecimal scale. In answer, Delambre mentions, that this question was the first to which he and his co-commissioners had directed their attention, and that their inquiries were aided by the appearance of a work in German, which contained a complete system of duodecimal arithmetic, in two volumes. They were then at the same stage of the inquiry, at which those English philosophers are arriving now, who think it is still a matter for consideration, whether we should not endeavour to establish a complete system of arithmetic on a duodecimal plan, as a preparation for a duodecimal system of Measures, Weights, and Coins. See the answers of G. W. Hemming, Esq., and others, to Lord Overstone's Questions, London, 1857, p. 85, &c.

I will here observe, that the best account of the operations for determining the metre, with which I am acquainted, and which is easily accessible to English readers, is in the 11th volume of Rees's Cyclopædia, London, 1819, art. DEGREE. It was compiled by John Pond, F.R.S., Astronomer Royal.

"We cannot finish our account of these scientific operations," says Professor Playfair, "without expressing our wishes, that the uniformity of measures and of weights were introduced into our own, and into every other civilized country. The difficulty is not so great as we are apt to think, when we consider the matter at a distance; *and to effect it requires in reality nothing but for the Legislature to say, it shall be done.* As to the standard to be adopted, though we think the pendulum would have afforded the most convenient, yet when one has been actually fixed on and determined, that circumstance must greatly outweigh every other consideration. The system adopted by the French, if not absolutely the best, is so very near it, that the difference is of no account. In one point it is very unexceptionable; it involves nothing that savours of the peculiarities of any country: insomuch, as the Commissioners observe, that if all the history, which we have been considering, were forgotten, and the results of the operations only preserved, it would be impossible to tell with what nation this system had originated. The wisest measure, therefore, for the other nations of Europe is certainly to adopt the Metrical System. * * * It would not be necessary to adopt their names, which might not assort very well with the sounds that compose the languages of other nations. But *the metre*, by whatever name it may be called, *ought to be adopted as the unit of length*, and all the other measures of linear extension derived from it by decimal multiplication and division. It is true that this cannot be done, especially in our own case, without a certain sacrifice of national vanity; and the times do not give much encouragement to hope that such a sacrifice will be made. The calamities, which the power and ambition of the French Government have brought on Europe, induce us to look with jealousy and suspicion on their most innocent and laudable exertions. We ought not, however, to yield to such prejudices, where good sense and argument are so obviously against them."

VI. ARE THE BINARY DIVISIONS OF THE METRE CONVENIENT?

Although the fundamental principle of arrangement throughout the Metrical System, including Measures, Weights, and Coins, is that of multiplying and dividing by 10, the prime numbers 5 and 2, producing subor-

dinate binary multiples and subdivisions, hold a very prominent and important place. Each measure, as well as each weight and each coin, has its half and its double, with the necessary exception of those at the top and bottom of the scale. The principal denominations being thus produced by multiplying or dividing them by 10, and being further multiplied or divided by 2, the system is throughout binary as well as decimal. The result is the greatest possible facility of application, both in accounts and in all trades and manufactures.

In the English linear measures, two instances of binary division deserve notice; viz., 1st, the division of the yard into its half, its quarter, its eighth, and its sixteenth, or nail, used by drapers;* and, 2ndly, the division of the inch in the same manner by joiners.† There is evidently a great defect in having two classes of binary divisions, subordinate to the one unit of length, the yard; and it is further a great inconvenience that these do not harmonize with the established legal divisions of the yard into feet and inches. The half yard is $1\frac{1}{2}$ feet; the quarter is $\frac{9}{4}$ of a foot, or 9 inches; the half quarter is $4\frac{1}{2}$ inches; and the nail is $2\frac{1}{4}$ inches. The very indistinct relation to the standard of the binary system used by joiners is shewn by the following table:

$\frac{1}{72}$ yard $= \frac{1}{24}$ foot $= \frac{1}{2}$ inch.
$\frac{1}{144}$ yard $= \frac{1}{48}$ foot $= \frac{1}{4}$ inch.
$\frac{1}{288}$ yard $= \frac{1}{96}$ foot $= \frac{1}{8}$ inch.

* It may be observed that the nail is the 32nd part of a fathom, which carries the binary division a step further. But it is so only in theory; for in practice we never speak of a yard as half a fathom, nor do we commonly think of a fathom as two yards, but as six feet.

† For fine work, the 32nd also is used by joiners. It is not, however, marked on the scale, and it is called half-a-sixteenth.

In the use of the metre the binary division may, if it be necessary or desirable, be carried even to the eighth degree. For the myriametre admits of bisection 8 times. The 8th power of 2 is 256, and

$$1 \text{ myriametre} = 256 \times \underset{\text{metres}}{39} \quad \underset{\text{millimetres}}{62.5},$$

whence it follows that 39 metres and 62½ millimetres is the length obtained by dividing a myriametre by 2 for 8 times in succession.

But the fact is, that in linear measures, except as used by joiners, bisection is never required beyond the third degree, and seldom beyond the second. Few persons comparatively know what is meant by the eighth of anything. Drapers, silk-mercers, and their customers, although their cloth-yard is divided binarily down even to the sixteenth, never think of *the eighth of a yard* as such, but, adopting the nail as a secondary unit, they call the eighth *two nails*, or else they call the same quantity *half a quarter*.* In like manner, though we talk and think habitually of half a mile, and a quarter of a mile, yet, when we wish to go a step further in the bisection, we rather adopt a new unit, and call the eighth of a mile *a furlong*. These facts seem to indicate, that in linear measures binary

* These remarks are not in accordance with certain statements in the Report of the Commissioners "on the Restoration of the Standards," 1841, which are quoted by Dr. I. E. Gray in his evidence before the Commissioners on "Decimal Coinage," 1857. The witnesses, ignorant to all appearance, that the Metrical System makes the fullest provision for reckoning by halves and quarters, tell us, that, if a decimal method were introduced in this country, "ladies would still insist on buying silks or such articles by the yard, half, quarter, eighth, or sixteenth." If the Commissioners had examined the wives and daughters of these gentlemen, they would have discovered, that, when a lady pays for the sixteenth of a yard of silk, she scarcely knows that it is a sixteenth, and certainly does not conceive of it as such, but as a distinct length, called *a nail*. In like manner she never thinks of a quarter of a yard as the eighth of a fathom.

division is of little or no practical importance beyond the second degree, that is, the quarter: and, if so, the Metrical System was wisely adjusted by its inventors to the requirements of the human mind by the continual recurrence of that relation, in which it presents quantities of every kind, viz., the relation of the whole, the half, and the quarter.*

As the English cloth-yard is divided by studs into halves, quarters, half-quarters, and nails, the metre may be divided, if it be found expedient, in the same manner. I think it probable, however, that experience will lead to the rejection of binary division beyond the second degree. To this extent the use of the metre is greatly facilitated by having it made to fold. If made four-fold, it shews the halves and quarters manifestly to the eye, and ready for use, as it is opened or closed. The half-metre also may be made with hinges to fold either once or twice. When twice folded, its length is the eighth of a metre, or 125 millimetres. In like manner the decimetre, and even the half-decimetre, may be made to fold with a hinge, shewing the length of 25 millimetres, equal to one inch.†

* These remarks are quite in accordance with the evidence of the witnesses, published by the Three Commissioners on Decimal Coinage.

"Few shopkeepers would bisect more than twice, rarely more than once." The Very Rev. Dr. Peacock.

"In marketing, generally, beyond halves and quarters, people do not divide. When halves and quarters fail them, they go down to a lower denomination."—"A bisection is, no doubt, more easily made than any other section; but there does not appear to be any natural tendency to subdivide commodities by continual halving; a board, for instance, or a piece of cloth." Mr. William Miller.

"Answers to Lord Overstone's Questions," pp. 11, 7, 37, 8vo edition.

This "natural tendency" is assumed by Lord Overstone in his 38th Question. If the assumption were true, no persons, when they go a-shopping, would ask for *half-a-yard*, or a *quarter-of-a-yard* of cloth, but always for a *quarter*, or an *eighth of a fathom*.

† The *inch* is the 10th, 11th, or 12th part of the *foot*, and further varies in different countries as the foot itself varies. The inch, used in Hesse Darmstadt, is exactly 25 millimetres, being the 40th part of a metre.

VII. Are the Multiples of the Metre convenient for large measurements and geographical purposes?

The multiple, of which the most frequent mention is made, is the kilometre, nearly equal to the Russian verst,* and to five furlongs English. For itinerary measures nothing can be more convenient. The measures between this and the metre serve extremely well for smaller distances, such as we conceive in reckoning the dimensions of a dwelling or an estate, or in describing a walk through a town or village.

The land-chain belonging to this system, consists of 50 links, each of the length of 2 decimetres, so that 5 links are equal to 1 metre, and the chain is equal to 10 metres, or one decametre. The double decametre, also commonly used in measuring land, is within a few inches of the English land-chain. But the English, being computed by a most awkward combination of the prime numbers, 2, 3, and 11, bears no comparison with the metrical chain in regard to convenience and facility of application. It may also be noted, that 10 double land-chains, i. e. chains of 20 metres each, are nearly an English furlong.

The double metre, which is sometimes made to fold with a hinge, may be compared to the Roman decempeda. It serves the same purpose as the rod of five feet, or rather that of ten feet English, used for brickwork, parts of buildings, and gardens, laying out grounds, measuring carpets, floor-cloths, &c. In Switzerland and some parts of Germany, a measure of three metres is used in the same way.†

* The verst is 1066 metres.

† See below, pp. 61, 62.

The myriametre, equal to 10 kilometres, also seems adapted to be useful. It is the 1000th part of the quadrant of the meridian as computed for the Metrical System; and, as the use of the globes is a part of general education, children are thus enabled to acquire a good general notion of the dimensions of all the principal divisions of the earth. Moreover, the myriametre, being much longer than the mile, the league, or any other denomination of linear extension used for very great distances, in general expresses them in fewer figures, and in terms better adapted for conception and calculation.

VIII. ARE THE SUBDIVISIONS OF THE METRE CONVENIENT FOR SMALL MEASUREMENTS, SUCH, FOR INSTANCE, AS ARE REQUIRED IN MAKING MACHINERY AND DELICATE INSTRUMENTS OF ALL KINDS, AND IN ALL MANNER OF SCIENTIFIC INQUIRIES AND DESCRIPTIONS? ALSO, ARE THESE SUBDIVISIONS USEFUL IN ORDINARY TRADES, SUCH AS THOSE OF TAILORS, MILLINERS, SMITHS, WATCH-MAKERS, CABINET-MAKERS, ENGINEERS, AND OTHER ARTIFICERS?

These subdivisions are the decimetre, centimetre, and millimetre. The scale is also often divided into half-millimetres; but below that, the division must be imagined or computed, as it cannot readily be marked in lines, or made visible to the naked eye.

The decimetre is equal to about 4 English inches. Indeed, it may be considered as identical with the measure which we call the *hand*, because it corresponds with the ordinary breadth of the human hand. It is so well fitted to be carried about the person and applied

to all kinds of uses, that it is made in a great variety of forms, but principally in scales of 3 decimetres, which is the unit of linear measure in parts of Germany and in Switzerland, also of 2 decimetres, 1 decimetre, and half a decimetre. The scale of 3 decimetres is sometimes made with a slide, so as to measure more than the length of half a metre, and to be adapted to measure cavities and hollow vessels, besides being convenient to carry in the pocket. In short, it answers every purpose of the joiner's foot-rule in England, with all the additional advantages of a decimal division, much finer than that into eighths of an inch.* The scales of 1, 2, or 3 decimetres, without a slide, may be be made to fold with a hinge.

All who have accustomed themselves to use the metre, are struck with admiration at the convenience and beauty of its smaller divisions, called centimetres

* Mr. Simon Holland seems not to be aware how extensively the foot of three decimetres is used on the Continent, nor indeed to know any form or division of the metre except that which is adopted partly by reason of its cheapness, being sold in the markets for a penny. But I quote the following testimony, as from an enemy, and still favourable to the scale of which I am speaking:

"Such lengths (as the pendulum and the metre) could never be made to serve for a mechanic's rule; and yet there is nothing in the whole range of measures and weights of anything like the importance of a foot-rule; if a system break down in that particular, it breaks down altogether. If it fail to give to the mechanic as good a rule as the old pied, or the English foot, it is a failure indeed. See the number of uses to which a mechanic puts his foot-rule, when the metre would be entirely useless. A good slide rule is a ruler, a straight-edge, a bevel, frequently used as a square, a guage, &c. &c. The sun never sets on the English foot-rule; it is always in use, its uses are so many. By means of its slide, it forms a perfect guage for measuring the depth of holes, and the internal diameter of cylinders, within its range, and offers a useful and ready calculating machine, the use of which is readily learnt." Mr. Simon Holland in Mechanics' Magazine, Vol. LXV. No. 1733, p. 392.

It is obvious that these purposes are accomplished equally by the use of a scale of three hands, or decimetres, made with a slide.

and millimetres. In England they are, nevertheless, objected to by some, who profess to have studied the subject, but who object on opposite grounds. Sir Chas. Pasley says the millimetre is "so very minute as to be quite unsuited to the mechanical arts," and that "a vigorous carpenter would demolish 5 or 6 millimetres of the hardest wood with one sweep of his jack-plane."* On the other hand, Mr. Simon Holland says it is too large, since "our wire and sheet-metal guages, expressed in millimetres, would require the use of two decimal places."† Thus the opponents of the metre neutralize one another's objections, and leave us to the conclusion, that nothing could be better adapted than the millimetre for minute measurements. Besides, as an answer to the assertion that the millimetre is too large, I have already stated (p. 51), that the scales are often graduated into half-millimetres. By the use of them, the parts of a machine may, if required, be made true to the 10th or the 100th part of a millimetre, or even to a much less quantity. Messrs. Sharp Brothers & Co., of Manchester, make their machinery true to the 100th part of a millimetre.‡ The celebrated instrument-maker of Paris, M. Fortin, invented a comparer, which measured the 500th part of a millimetre, and which was used by Biot and Arago in their experiments on the second's pendulum.§ But this kind of accuracy has lately been carried still further. The standard metre of Fabre and Kuneman, exhibited at Paris, was adjusted to the 1000th part

* "Observations on Measures, Weights, and Money," p. xiii.

† Mechanics' Magazine, Vol. LXV. p. 417, Nov. 1856.

‡ See below, p. 75.

§ Biot et Arago, "Receuil d'Observations Géodésiques," Par. 1821, p. 448.

of a millimetre,* thus shewing 3 gradations descending from the kilometre, and of 1000 equal parts in each gradation. These facts may enable us to determine, whether we ought to concur with those who allege that the divisions of the metre are not sufficiently minute, or whether we shall coincide with such a judge as Professor W. H. Miller, of Cambridge, who pronounces the subdivisions of the metre to be "much more convenient than those of any other unit."†

Before quitting the subject of small measures, let it be observed, how requisite they are to accuracy in buying and selling. In England, it is impossible for persons to buy exactly what they want, partly because there is no coin small enough, and partly because the modes of measurement are unsuitable. Suppose a person to buy fractional parts of a yard of ribbon at $5\frac{1}{2}d.$, $6\frac{1}{2}d.$, or $7\frac{1}{2}d.$, or of calico at $3\frac{1}{2}d.$, $4\frac{1}{2}d.$, or $5\frac{1}{2}d.$, it is manifest that the thing cannot be done with accuracy. Either he or the shopkeeper must make an involuntary sacrifice. But, when articles of drapery and similar goods are measured by centimetres, the low monetary unit being also divided into hundredths, so that the coins are adjusted to the measures, every quantity may be calculated and every debt discharged with absolute justice and without the slightest difficulty.

* Abbé Moigno's "Cosmos," Vol. VII. p. 500.

† Private letter to the author. "It so happens," observes Professor Miller in his answers to Lord Overstone (p. 31, 8vo edition), "that the magnitude of the kilogramme and its subdivisions, as well as of the metre and its subdivisions, renders them much more convenient for use than our lb. and the yard with its subdivisions into inches and tenths or eighths."

IX. HAS ANY OTHER UNIT OF LENGTH BESIDES THE METRE BEEN PROPOSED FOR GENERAL ADOPTION THROUHOUT THE WORLD, AND APPLIED IN PRACTICE?

Although the second's pendulum was proposed for universal adoption, as above stated (pp. 12—19), it did not come into use. The metre is the only unit of length, which has been offered to the world and to a great extent accepted by the world.

The most distinguished and strenuous opponents of the metre, who, with the exception perhaps of the unknown writer in the Penny Cyclopædia, are all members of the two celebrated Universities of Cambridge and Berlin, with one voice conclude their objections by denouncing the metre as "arbitrary" *(willkürlich)*. It is difficult to conceive in what sense these learned men employ the epithet. For their own arguments prove, that the metre is not arbitrary in the usual acceptation of the term. A thing is called arbitrary, when it is supposed to be fixed without reasoning and without consulting others, by the mere will and pleasure of him who ordains it. The Queen of Heaven was arbitrary, as represented by the poets, when she said,

Sic volo, sic jubeo, stat pro ratione voluntas.

Henry I. of England was arbitrary, when he declared that all his subjects should take the length of his own arm as the unit of linear measure. The feudal lords of France were arbitrary, when each local *seigneur* required his vassals to take the length of his cane for their ell, and the size of his wine-glass for their standard of capacity. In a similar arbitrary manner it is probable, that all weights and measures were first intro-

duced, until the great proposal in 1789, which led to the promulgation of the metre after ten years of most careful inquiry and anxious deliberation. In this respect the metre widely differs from all other units of length, so far as we have any knowledge. In no other instance were delegates appointed from different countries to confer together for the general benefit. In no other case were the highest applications of science employed with a decisive result. In no other did philosophers, mathematicians, and statesmen of all the principal countries of Europe, with the exception of England and Germany, unite to offer their counsels and their labours. In short, all the units of length, antecedent to the metre, may have been arbitrary; this had an entirely different origin. The aim, as grand in its conception as it has been successful in its accomplishment, which led to the adoption of the metre, ought to secure for it the most respectful and attentive consideration, even if valid and tenable objections could be adduced against its accuracy.

X. To what extent is the Metre already adopted, or decreed to be adopted, in Foreign Countries?

France.

The French law enacted on the 7th of April, 1795, is as follows: "There shall be only one standard of Weights and Measures for the whole republic. It shall be a bar of platinum, on which shall be traced the *metre*, which has been adopted as the fundamental unit of the whole system of measures." This law has been in force ever since its enactment, and, notwithstanding frequent and violent interruptions from poli-

tical causes, it has been continually displacing the *aune* and other measures, so that its employment in France is almost universal. If a few old persons are still attached to the *aune* from habit, the use of it must expire with their lives.*

In the cotton manufacture, the Metrical System is applied as follows. The yarn is wound in skeins, called *échevettes*, each 100 metres long. Ten *échevettes* make an *écheveau*, which consequently has the length of a kilometre. It is then ascertained how many hanks, or *échevaux*, are required to weigh a pound, or half-kilogramme, and the number, so determined, denotes the fineness of the yarn. The finer the yarn, the higher is its number, and the higher its price per pound. To some extent the Metrical System is applied also in the spinning and weaving of flax, wool, and silk.†

Belgium.

The Code of Laws and Regulations published in 1855, contains the following provisions:

"The Decimal Metrical System of Weights and Measures, established by the law of Aug. 21st, 1816, remains in force through all Belgium."

"The metre and the kilogramme deposited at the Chamber of Representatives in pursuance of the law of March 4th, 1848, are the prototype standards of weights and measures. These standards are preserved in a case (armoire) under three keys, one of which is entrusted to the President of the Senate, another to the President of the Chamber of Representatives, and the third to the Minister of the Interior."

"The use of weights and measures other than those established by the law, is forbidden."

* Tarbé, "Manuel des Poids et Mesures," 5ème Partie, "De la Legislation."—"Annuaire du Bureau des Longitudes."

† "Comptes Rendus," for 1838, p. 788. "Noback, Muntz-, Maass-und Gewichts-buch," Leipzig, 1855, 8vo, p. 563.

In the year 1838, King Leopold procured the necessary standards from Paris.*

Every ten years the secondary standards, kept at the Ministry of the Interior, are compared with the prototypes, in the presence of the three above-named functionaries, who hold the keys. The divisions and denominations of the linear measures are exactly the same in Belgium as in France. These measures cannot be verified and punched, if marked with the old divisions.

The Belgian Government spares no pains to facilitate the use of the metre, though lenient in enforcing the law. The old measures are still extensively used. The Belgians, rather than change their habits, love to cheat, and are willing to be cheated.

Holland.

With the exception of the old nomenclature, the weights and measures of Holland, since 1817, have been according to the Metrical System. The names still used, are as follows:

The *streep*	is the	millimetre
„ *duim*	„	centimetre
„ *palm*	„	decimetre
„ *ell*	„	metre
„ *roede*	„	decametre
„ *mijle*	„	kilometre.†

Sardinia.

When the British Branch of the International Association addressed the King of Sardinia on his visit to London, His Majesty returned a most gracious

* Tarbé, "Manuel des Poids et Mesures," p. 364.

† Woolhouse, "Measures, Weights, and Moneys of all Nations," Lond., 1856, p. 78. Noback, p. 30.

answer through his Ambassador, dated Jan. 22nd, 1856, stating that the Metrical System was in force throughout the Sardinian dominions, and productive of the happiest results.* Since then the Decimal Coinage Commissioners have sent their queries to foreign countries, and have obtained from Turin full particulars respecting the introduction of the Metrical System in these territories.† It appears that by an Edict issued in September, 1845, the 1st of January, 1850, was appointed for the general establishment of the Metrical System throughout the kingdom. The interval was employed in obtaining the standards, in making and verifying copies of them, publishing tables, printing elementary treatises and circulating them by thousands, and in other preparatory efforts, which resulted in the establishment of the system, not by the force of arms, as has been repeatedly asserted in this country, but with the general concurrence and satisfaction of all classes of the community.

Lombardy.

The linear measures of the Metrical System were introduced in 1803, and are still in force, but under Italian denominations as follows:

The	*atomo*	is the	millimetre.
„	*dito*	„	centimetre.
„	*palmo*	„	decimetre.
„	*metro*, or *braccio*	„	metre.
„	*miglio*	„	kilometre.
„	*lega*	„	myriametre.‡

* Yates, "Narrative of the Origin and Formation of the International Association," pp. 54—56.

† "Preliminary Report of the Decimal Coinage Commissioners," Lond., 1857, pp. 228, 229, 239—241, 258, 259.

‡ Woolhouse, p. 110. "Preliminary Report," p. 300. Noback, p. 457.

GREECE.

The Metrical System was authorized by a royal ordinance in 1836, but is not yet extensively used.* The Government ordered its standards at Paris.†

SPAIN.

On the 19th July, 1849, a law was passed, ordaining the establishment of the entire Metrical System, but allowing an interval of ten years for its introduction. This interval is occupied in preparatory measures. The Queen some time ago decided, that after the 3rd of January, 1856, the metre should be used in all announcements of the sales of national property.‡

PORTUGAL.

A decree has been adopted analogous to that in Spain, by which the Metrical System is to be established at the close of the year 1862.§

SWITZERLAND.

It appears that the Federal Council has decreed the adoption of the entire Metrical System, but has hitherto only ventured to introduce it partially, and in a very modified form. It has altered the foot so as to make it 3 decimetres long, and with this modification it remains as the unit of length, its multiples being only in part decimal. Hence the following system of linear measures is for the present established:

* Woolhouse, p. 73. "Preliminary Report," p. 329. Noback, p. 53.

† Saigey, "La Pratique des Poids et Mesures," p. 167.

‡ "La Presse" (Paris), Jan. 25th, 1856. Noback, p. 445.

§ "Preliminary Report," p. 318.

	Swiss Feet		Metres
1 stroke *(strich, trait)* . =	.001	=	.0003
1 line *(linie, ligne)* . . . =	.01	=	.003
1 inch *(zoll, pouce)* . . . =	.1	=	.03
1 foot *(fuss, pied)* . . . . =	1.	=	.3
1 yard *(elle, brache)* . . =	2.	=	.6
1 ell *(stab, aune)* . . . . =	4.	=	1 2
1 fathom *(klafter, toise)* =	6.	=	1.8
1 perch *(ruthe, perche)* =	10.	=	3.
1 league *(stunde, lieue)* =	16000.	=	4800.

The Federal Council, in their answers to the Decimal Coinage Commissioners, further state, that some of the Cantons did their utmost to introduce the Metrical System without any modification, and that, if they were beginning now, the Swiss would probably prefer the simple Metrical, to the mixed System, as being the most likely of all systems to become universal.*

Germany.

The metre is universally adopted in scientific treatises.† Also the Railway Engineers of Germany, in their conference at Vienna in May, 1857, unanimously determined to use two columns in denoting distances, and to express those distances in metres in the first column, and in Swiss feet of 3 decimetres each in the second.‡ Moreover, "French goods are almost universally sold by the metre, at least in wholesale transactions."§

The following information is given by Dr. Souchay, one of the principal citizens of Frankfort-on-the-Maine:

"The system of weights and measures legally adopted at present

* "Preliminary Report," pp. 281, 282, 291. Noback, p. 660.

† Vogt, "Lehrbuch der Geologie," Vol. I. p. 17.

‡ "Moniteur des Interêts Matériels," Brussels, 21 Juin, 1857.

§ Dr. Otto Hübner, in Yates's "Narrative," p. 42.

in Frankfort is the Metrical System; nevertheless, many other weights and measures are in use for different objects, which custom has introduced, and which will probably be lost with time and by the operation of a contrary custom. * * * This system has made great progress in Germany during the last twenty years. It is universally admitted that it is the best, and every change that has taken place has been in its favour. The difficulties which oppose its general introduction are merely financial, every change affecting so many interests. But wherever a change is made, the Metrical System will be adopted."*

The smaller German States, bordering on Switzerland and the South of France, have made advances in different ways towards the Metrical System, but are afraid of going the whole length, so as to partake of its full advantages. The following table of the measures adopted in the Grand Duchy of Baden agrees generally with that of Switzerland.† The names are of course German. The smallest measure, called the *punkte*, or *point*, is equal to $\frac{1}{10}$ of a millimetre.‡

		Metres
1 point (*punkt*)	=	.0003
1 line (*linie*)	=	.003
1 inch (*zoll*)	=	.03
1 foot (*fuss*)	=	.3
1 fathom (*klafter*)	=	1.8
1 rod, pole, or perch (*ruthe*)	=	3.

On the other hand, the Grand Duchy of Hesse-Darmstadt reduces its unit, the foot, to the length of $2\frac{1}{2}$ decimetres, and the following series is the result:§

		Metres
1 line (*linie*)	=	.0025
1 inch (*zoll*)	=	.025
1 foot (*fuss*)	=	.25
1 fathom (*klafter*)	=	2.5

* Yates's "Narrative of the Origin," &c., p. 39. † See above, p. 61.
‡ Woolhouse, p. 54. Noback, p. 310.
§ Woolhouse, p. 77. Noback, p. 174.

The Hessians have also a cloth-yard (*elle*) 6 decimetres in length. By means of this, which is divided into quarters, eighths, and sixteenths, they dovetail their system into that of Switzerland and Baden, besides having a point of contact with the Metrical System.*

Africa.

The cable which now takes telegrams from Europe to Africa, was preceded by the metre. The island of Sardinia received it from Piedmont, Corsica and Algeria from France. Its general introduction along the northern and western coasts of Africa may be expected at no distant period. Mr. Roberts, late President of Liberia, has informed me both by conversation and by letter, that his country will not hesitate to receive the Metrical System, whenever England and the United States of America shall set them the example.† In like manner the Portuguese colonies

* See above, pp. 61, 62.

† The following letter from Mr. Roberts will be gratifying to every philanthropist:

"London, May 26th, 1856.

"Though residing far from the centre of civilization, and but imperfectly informed in regard to the many important measures proposed for the improvement of society, I have learned something, I am happy to say, of the new 'International Association,' and do most heartily approve the measures of reform proposed. I am fully satisfied, that the uniformity of measures, weights, and coins throughout the civilized world would not only facilitate commercial intercourse, but would also greatly tend to strengthen the bonds of union and harmony between nations.

"I am greatly obliged, Sir, by your assurance of the satisfaction it would afford the Officers and Council of the International Association to have Liberia brought into the contemplated union. I am sure the people of Liberia will be most happy to contribute their mite to your effort. In Liberia the new system could be easily adopted; in England and some other countries, I am aware, great inconveniences for a time would arise. But in my humble opinion the measure is not only practicable, but does not involve the many serious difficulties, which are in some quarters contemplated.

"I have the honour to be, my dear Sir, your obedient, humble servant,

"I. I. Roberts.

"To James Yates, Esq."

on the western coast of Africa will follow the mother country, which has already adopted the metre, and its adoption throughout South Africa is sure to succeed to a similar reform, whenever it shall be encouraged by Great Britain.

West Indies.

It is to be expected that those islands, which are colonies of France, or which shall be colonies of any country using the Metrical System, will be disposed to accept the metre as their unit of length. It is so already in Martinique and Guadeloupe.* The island of St. Domingo, which is not a colony, will probably follow, or rather perhaps take the lead, in the same track. Baron Damier, envoy of the Haytian Empire to the Court of St. James's, states that his countrymen are inclined to this course.

North America.

Although, as far as I am aware, the metre has not been practically adopted in any part of the United States, except for scientific purposes, the opinion in favour of its adoption has been so strongly expressed by persons high in both intellectual and official position, that I think it proper to include this portion of the globe in the present enumeration. The fact is, as shewn by the authors referred to, and especially by President Adams, that the United States only wait to see the first move made by Great Britain. For the evidence on this subject I must refer to my "Narrative of the Origin and Formation of the International Association," 2nd edition, pp. 9—11, 17, and Appendix, No. iv., and to my essay printed and privately

* Noback, p. 474.

circulated under the sanction of the Institute of Civil Engineers, pp. 24, 28, 29.

The Metrical System has been for some time adopted in Mexico.*

South America.

In no part of the world has the Metrical System advanced so rapidly as in South America. No sooner had the people obtained the advantages of settled government than they directed their attention to the reform of their incongruous methods of measuring and weighing and of reckoning money. The result has been that one republic after another, and almost year by year, adopted the metre as the unit of length, and sent to Paris for standards. This has been the case for a considerable number of years in Chili, Columbia, and New Granada.† More recently the entire Metrical System has been adopted by the republic of Ecuador.‡ Paraguay, Costa Rica, and the Argentine Confederation, are represented in the Central Committee of the International Association.§ The remaining populations, such as those of Brazil and Guiana, being either colonies or off-sets of European countries, may precede, but will perhaps more naturally follow, the steps of those nations, with which they are most intimately connected. Brazil follows Portugal.‖ Guiana will

* "Description du Système Métrique," par W. W. Mann, Citoyen des Etats-Unis. Paris, 1853, p. 11.

† "Description," &c., par W. W. Mann, l. c. "La Presse," Paris, Jan. 25th, 1856. Noback, p. 653.

‡ Private letter from M. Michel Chevalier, dated June, 1857.

§ Yates's "Narrative," p. 2.

‖ Woolhouse, "Weights and Measures," p. 58. Saigey, "La Pratique des Poids et Mesures," pp. 165, 166.

agree with France and Holland, partially under present circumstances, and entirely as soon as England shall agree with the French and Dutch. Thus it appears in the highest degree probable, that the whole of South America will be speedily united in the use of the metre and its derivatives.

XI. Is the use of the Metre now authorized by law in the United Kingdom of Great Britain and Ireland?

The metre was singularly distinguished and its importance virtually acknowledged in the Resolution of the House of Commons, March 15th, 1816, which has been already quoted in § II. I am not aware, that any other foreign unit of length has been noticed in this marked manner by the British Legislature. An important result of the inquiry then instituted is, as it appears to me, the legality of the metre in the British dominions.

The Commissioners of 1816 were instructed to direct their attention to two points, the length of the second's pendulum, and the length of the metre, as compared with the standard yard. They reported, A.D. 1820,

	Inches
The length of the second's pendulum	= 39.13929
The length of the metre	= 39.37079.

The former of these determinations was after a few years set aside as incorrect.* The latter has never been impugned, but is to this day universally accepted

* See above, pp. 20—22.

as an accurate statement of the length of the metre in terms of the authorized English linear measures.* It is found as the equivalent of the metre in such standard and popular French books as the "Annuaire du Bureau des Longitudes" and Galignani's "Paris Guide;" in the works of Noback on Weights and Measures in German; and on this side of the Channel in all similar publications, such as Thomson's "British Annual," Woolhouse's manual, frequently quoted above, Webster's "Court Guide," and the pocket-books of De la Rue, Gutch, Goldsmith, and others. The most improved school-books for teaching arithmetic in this country give the same length for the metre, and add lucid accounts of the system of weights and measures founded on it.† Now the English Weights and Measures Act, whilst it prescribes a system for general use with some peculiar advantages, allows of the use of other weights and measures, provided that their proportion to the standards is ascertained and generally known, and also "painted or marked" upon the weights and measures so employed.‡ Hence the metre with its multiples and subdivisions, being as generally known and as clearly and authoritatively defined as any local or customary measure whatsoever, appears to be sanctioned by the law as it now stands.

* For the sake of avoiding too many decimal places, 39.371 is often substituted for 39.37079. The difference of $\frac{21}{100000}$ is disregarded. The addition of this minute quantity, nevertheless, does more to prolong the metre than is required by any of those persons, who object to it on the ground of inaccuracy. Indeed this addition would make the metre too long instead of being too short.

† Bishop Colenso's "Arithmetic for the Use of Schools," p. 140; Cornwell and Fitch's "Science of Arithmetic," pp. 315—322; Galbraith and Haughton's "Manual of Arithmetic," pp. 157—160, 178.

‡ See the statute, 5 Geo. IV. c. 74, § 16.

The metres, used in this country, are commonly "painted or marked," as the Act directs.

Moreover, any Englishman, who wishes to obtain a standard yard, will probably find the following, at least in many situations, to be the easiest road to the attainment of his object, viz., to refer to a standard metre, such as he may find in the capital of almost every civilized country, and to have his yard made according to the following ratio:

THE METRE IS TO THE YARD AS 39.37079 IS TO 36.*

* The way, in which this proportion was found by Captain Kater, is described in the "Phil. Transactions of the Royal Society" for 1818, pp. 103—109. Two metres of platinum were made in Paris under the superintendence of Arago, exactly equal to the prototype in the Archives. These were brought to London and deposited in the apartments of the Royal Society. They are in excellent preservation, not being defaced by file-marks, or any other perceptible inequality. From a very exact comparison of them with Sir G. Shuckburgh's standard yard, Captain Kater ascertained, that the metre, taken at its normal temperature, that of melting ice, was equal to 39.37079 inches of the said yard, taken also at its normal temperature, that of 62 deg. Fahrenheit.

The following passage from a subsequent memoir by Captain Kater is also important in relation to the universal acceptation of his measurement of the metre. Phil. Trans. for 1821, p. 92.

"The Commissioners of Weights and Measures proposed, in their Second Report (A.D. 1820), that Bird's Parliamentary standard of 1760 should be considered as the foundation of all legal weights and measures. It may be seen, that the standard thus selected differs so little, if at all, from that of Sir George Shuckburgh, that they may, for every purpose, be considered as perfectly identical; and this agreement is particularly convenient, because the length of the metre having been determined by comparisons with Sir George Shuckburgh's scale, and a fac-simile of it made by Mr. Troughton for Professor Pictet, all measures on the Continent are converted into English measure by a reference to Sir George Shuckburgh's standard."

In Professor Barlow's "Mathematical and Philosophical Dictionary," London, 1814, art. MEASURES, the metre is estimated at 39.371 English inches; but this was prior to Captain Kater's experiments. In regard to Pictet's fac-simile, the reader may consult Prony in the Base du Système Métrique, Tom. III. pp. 476—479.

XII. To what extent is the Metre now used in the United Kingdom?

In order to estimate the importance, which is to be attributed to the metre in its relation to English ideas and habits, it appears desirable to ascertain, as far as possible, what place it occupies in comparison with the English unit of length, the yard, in the foreign transactions of Great Britain. For this purpose, let foreign nations be supposed to be divided into two classes, those which use the yard, and those which use the metre, as their unit of length. It will be necessary to leave out of the account many comparatively small countries, which retain the English measures, such as Jamaica, the Cape of Good Hope, and Demarara, for want of information; and a far greater number of countries, which are more populous and of greater extent, and which employ the Metrical System, partly for the same reason, and partly because they use the metre in conjunction with other measures, though not with the yard. Such are the kingdom of Sardinia, Lombardy, Greece, Switzerland, the West Indies, and all South America. With these unavoidable omissions, the comparison will be made between the United States, Canada, and Australia, which use the yard, and France, Belgium, and Holland, with Spain and Portugal, which have adopted the metre. Further, we may endeavour to estimate the intercourse of Great Britain with these two groups of countries in three different ways, viz., their *epistolary* intercourse, estimated by the operation of the Post Office; their *commercial* intercourse, estimated by returns from the Board of Trade; and their *personal* intercourse, estimated by the number of passengers in steamers.

1. *The Third Report of the Postmaster-General on the Post Office*, exhibits, at p. 37, a table shewing in the first column the number of letters despatched in 1856 from the United Kingdom to certain colonies and foreign countries. The following numbers are extracted therefrom:

a. Number of letters sent to countries in which the *yard* is the unit of length:

United States of North America	1,733,745
Canada	358,284
Australia	913,733
	3,005,762

b. Number of letters sent to countries, in which the *metre* is the unit of length:

France	2,184,916
Belgium	325,811
Holland	233,632
Spain and Portugal	171,846
	2,916,205

2. A Return of *Trade and Navigation Accounts*, printed 16th February, 1857, by order of the House of Commons, exhibits at p. 19, a table shewing the number and tonnage of vessels cleared outwards to various countries in 1856. The following numbers are extracted therefrom:

a. Number and tonnage of vessels cleared to countries, in which the *yard* is the unit of length:

	Vessels.	Tons.
United States of North America	1602	1,493,506
British Possessions in ditto ...	909	389,622
Australia.	696	450,420
	3207	2,333,548

b. Number and tonnage of vessels cleared to countries in which the *metre* is the unit of length:

	Vessels.	Tons.
France	9077	1,138,488
Belgium	1090	204,472
Holland	2826	498,761
Spain	1481	271,810
Portugal	804	134,270
	15,278	2,247,801

3. The following are all the statements I have met with, shewing the *personal* intercourse between the two groups of countries:

a. United States of North America.

An article in the *New York Tribune*, copied in the *Times* of June 17th, 1857, asserts, that "in 1856 the number of Americans returning from Europe, who landed at New York alone, was 39,319."

b. France and Belgium.

According to a statement in the *Times* of Nov. 12th, 1856, the number of passengers between England and the Channel ports of the continent in 1855 was 313,580.

Mr. Apsley Pellatt also obtained a return shewing the number of passengers between France and England in the same year to have been 234,424.—*Times*, Feb. 21, 1857.

The following returns were given me at the office for Steamers to the Continent in Moorgate Street:

France	235,565
Belgium	38,518
	274,083

In the next year, 1857, the number appears to have amounted to 276,061,—*Times* of Jan. 29, 1858.

The following passage occurs in Mr. Monckton Milnes's speech in the House of Commons on Passports, March 23, 1858:

"The communication between the French and English coasts was so entirely free, that since the establishment of excursion trains nearly 100,000 persons had gone over from this country every year to enjoy themselves at Calais and Boulogne for a few days, and their visits had been a source of considerable profit to the inhabitants of those towns."

I have not been able to obtain accounts of the passengers to Australia and other parts of North America besides New York, on the one hand, nor to Holland, Spain, and Portugal, on the other. But from the very imperfect data laid before the reader, I am disposed to infer, that the number of passengers to countries using the metre far exceeds that to countries using the yard. Also, if we consider the great preponderance of countries using the metre to a greater or less extent, which are omitted in the above enumeration, I think it may be concluded, that our intercourse by letter, by commerce, and in person, with countries using the metre, is considerably greater than our intercourse in the same ways with the countries, colonized from Great Britain, which have persevered in employing the yard.

The preceding review of the external relations of Great Britain shews with what good reason and wise foresight Mr. Davies Gilbert and his associates in 1816 drew the attention of the Legislature to the metre. Its progress through the world since that time greatly enhances its importance to us. No well-informed person can now remain ignorant of its history and its application.* It appears to be coming more and more

* Under present circumstances all persons except secluded rustics should learn to answer the following question, which was proposed in Dec., 1855, to the pupils of the Normal College of the British and Foreign School Society:

"Make a list of the units of weight, measure, and value, employed in the Système Métrique. State what is the meaning of each term, and how the several units are related to one another."

into use in this country, being either indispensable, or at least very convenient, in the prosecution of various employments and professions.

An acquaintance with the metre is of no small importance to travellers and scientific men, whose works cannot be understood in foreign countries, unless they use the metre in their descriptions. Our great paleontographer, Professor Owen, uses this measure in conjunction with the yard, and finds in it the greatest possible facility, its subdivisions presenting advantages, which belong to no other scale. Professor Forbes, of Edinburgh, in his beautiful and instructive work on the Alps of Savoy, attaches to his Map a scale shewing the distances in kilometres. The late Colonel Jervis, in his table of "Indian Weights and Measures," has given their equivalents in the terms of the Metrical System as well as of the English methods. Professor Hennessy, of Dublin, uses the metre to mark all the instruments for his lectures on Natural Philosophy. Professor Robert Bunsen's Gasometry, a work lately translated into English by Dr. Henry Roscoe, the Chemical Professor in Owens College, Manchester, well illustrates the advantages of using the metre for the purposes of science. Professor Frankland, of St. Bartholomew's Hospital, is a decided advocate for the same practice. The Medical Society of Observation in London uses the metre in its statements on physiological and pathological subjects.

Our engineers, called to the execution of foreign railways and other undertakings, can only perform their task by abandoning the defects of their English habits and employing the incomparably superior method, which is recommended by the united voice of reason, science, and philanthropy. Chesterman's patent

metallic tapes, made at Sheffield, are marked on one side with the metre, divided into decimetres and centimetres, and on the other with the English foot divided into inches and half-inches. They are of various lengths, and are supplied in considerable and increasing numbers to English engineers, being sold in the shops of London and other places. Through the liberality of Messrs. Cutts, Chesterman and Co., of Sheffield, specimens of their measuring tapes are exhibited in the South Kensington Museum, Department of Education, together with a variety of metrical scales in wood and other materials.

In reference to this subject, the following important and decisive testimony was given before the Decimal Coinage Committee, in 1853, by Mr. Charles Hutton Gregory, C.E. (Questions 1428—1434):

"In all engagements referring to foreign countries, Mr. Gregory uses the Metrical System both as to money and measures. The result of his experience is a desire to see so good a system introduced into England. He considers the system as one, which is founded on good data and works well. He finds that estimates and calculations as to engineering operations are made very much more rapidly, and with very much less liability to error, by this than by the English method. He wishes for its introduction into England, because the inconvenience, which might arise from a change of all the measures now in use, would be overbalanced by its advantages, and by the prevalence of one universal system in all civilized countries."

The last question and answer by Mr. Gregory are as follows:

"1434. Would there be much difficulty in converting the French measures into English measures?—No: in the transition state, before men had forgotten to work with the old measures and learnt to work with the new ones, they could carry about with them multipliers, which would convert the old measures into the new, and artizans would probably carry rules, such as I continually carry myself, having the divisions of length marked according to two different systems, that is, on one edge the English measure, and on the other edge the

French measure, and which would become not only a rule, but a table by which one measure would at sight be converted into the other. Ultimately the rules of conversion would be unnecessary, because persons would get into the habit of working and thinking in the new measure. I found no difficulty, after having but a very short experience, in working and thinking in the French measures."

The manufacturers of steam-engines and other machines for exportation find the advantage of the same measurement. Mr. Siemens, whose improvements in the steam-engine are extensively adopted, uses the metre in all his designs; but for those works, which are made to British orders, he afterwards translates metres into feet. This gentleman exhibited at one of our meetings a set of measures and guages, adjusted to the metre, and used by Messrs. Sharp Brothers and Co., of Manchester, who have been distinguished for nearly half a century as the most eminent machinists in that city, and who now employ 1000 workmen.* Messrs. Negretti and Zambra, of Hatton Garden, use in their works a brass standard metre, made by Deleuil, of Paris. Messrs. Elliott, of the Strand, who have obtained a first-rate reputation as makers of astronomical and mathematical instruments, receive frequent applications for the metre, and supply it both for home use and for many foreign countries. In Liverpool metres are made by W. Baylis, 81, Dale Street, and are used at the Vauxhall Foundry and Fawcett's Foundry. Mr. Oertling, who is no less distinguished as a maker of philosophical instruments, and especially of the balances, which weigh with extreme precision, uses the minute divisions of the metre as best adapted to his purpose. Mr. Bennett, the eminent watchmaker in Cheapside, favours the metre, because it is so well suited to all the adjustments of machinery, and because

* See above, p. 53.

he makes the parts of watches separately for exportation, and thinks that a common system of linear measures is essential to the extension and improvement of his beautiful manufacture. "We must have," says he,* "a decimal mode of measurement enforced by law, and so precise as to define with mathematical nicety the size and proportion of all the parts."

Why should not the same reasoning be applied to other wheels than those of watches? The wheels of railroad carriages, for example, made to an international scale, might be exported from Britain to all parts of the world; and great improvements might be effected in proportion as such manufactures were conducted on a more comprehensive plan, and all calculations pertaining to them completed with superior skill and exactness.

These opinions may appear to have been contravened by the resolution adopted in June, 1857, by the Manchester Institution of Mechanical Engineers, pledging them to adopt a scale of one inch divided into 1000 parts.† But the question arises, What is to be understood by "an inch"? Many different inches are in use. Perhaps the inch intended was that used in Hesse and other parts of Europe, which is exactly the fourth part of a hand, or decimetre, and consequently equal to 25 millimetres.‡

* See his letter in the "Times" of March 28th, 1856.

† See the "Engineer" of July 3rd, 1857.

‡ See above, p. 49, note, and p. 62. According to the established proportion of the yard to the metre (see above, § XI.),

$$25 \text{ millimetres} = \frac{39{\cdot}37079}{40} = .98426975.$$

(English inches)

The Darmstadt inch therefore is less than the English by rather more than one part in 100. But the guages used by metal-workers in England are, I believe, seldom so finely made as to denote so minute a difference as this.

Fashions in dress being constantly transferred from Paris to London, it is not surprising that the metre should accompany them. The engravings, which exhibit them in the shop windows, are all drawn to the scale of one-tenth the natural size. A metre in the human frame is represented by a decimetre in the engraving. All the parts of the dress, being made to correspond to the decimal divisions of the metre, can be copied with ease in their full proportions. Explanations have been given in a periodical called the *Elegant*, each number of which contains a table comparing centimetres with inches and eighths of an inch. Tailors' measuring-tapes are made and sold in London, which are divided into centimetres, and are not only used by the foreign artists, but are coming into use amongst English tailors in consequence of their superior convenience.

Lastly, drapers and silk-mercers, as they purchase goods from countries which employ the metre, find it necessary to be acquainted with it equally with the yard. In London it is the practice in the principal shops of this class to have in their books double columns, so that the quantities are expressed both metrically, as they are imported, and in English cloth measure, as they are to be sold. Some shopkeepers of this class profess to sell by the metre. The various fabrics, such as merinos, silks, and ribbons, are made up in metres, unless orders are given to the contrary, by the use of excellent machinery adapted to the purpose, and the rolls or parcels have the quantities marked upon them in metres and centimetres.* To render

* Respecting the French practice, called *metrage*, which renders fraud next to an impossibility, I have been most kindly favoured with information by M. Arlès-Dufour, of Lyons, and M. Natalis Rondot, one of the Jury of the International Exhibition in 1855.

assistance so long as both measurements continue to be used, a card is sold by Effingham Wilson, 11, Royal Exchange, which shews, as nearly as can be done conveniently, the number of metres and centimetres corresponding to the yard and eighths of a yard, from one metre to one kilometre.

The metre, having thus obtained a footing in England, cannot be dislodged. On the contrary, if we regard its manifold intrinsic recommendations, its gradual progress in both hemispheres, and the continual increase of our communications with foreigners, and especially with the Continent, it seems that its more general adoption in the British islands is inevitable; and, since its general reception in this country must be accompanied with the most varied and substantial benefits, it is manifest, that as patriots, as philanthropists, and the enlightened friends of knowledge and civilization, we ought to accelerate its establishment as much as possible. If the members of our British Branch are disposed to decide in favour of the metre as the best unit of length, it will be their duty to communicate their opinion to the foreign Branches of the Association, by which the question will be in like manner considered; and, when they are prepared for the expression of a united opinion, a General Meeting of the entire Association will probably be called, or some other method may perhaps be pursued, for the declaration of their sentiments.

POSTSCRIPT.

The metre is gradually making its way in Russia just as in England. It is to a considerable extent employed, not only by men of science, but by engineers, drapers, tailors, and other artificers and tradesmen. A periodical publication, called the *Morskoi Sbornik*, or *Naval Magazine*, published at St. Petersburg under the authority of the Government, has lately inserted two articles, the first of which is by Mr. C. Kadinsky, and the second is a reply to it with the initials C. V. I have been favoured with a translation by Messrs. Thomas and John Michell.

Mr. Kadinsky disapproves of the decimal scale, but thinks that the system of Measures, Weights, and Coins, should be founded in nature, and he recommends as the unit of length a new foot equal to the 100th part of a second of the meridian passing through St. Petersburg. As far as regards the unit, his proposal is substantially the same as that of Sir C. Pasley (see above, p. 2), except that he would adopt as its foundation a new measurement of a meridian passing through St. Petersburg, instead of that proposed by the English Astronomer Royal. Also he departs from the Metrical System in dividing the assumed quadrantal arc into 32,400,000 new feet, instead of a thousand myriametres.

The writer (C. V.), who answers Kadinsky, shews an intimate knowledge of his subject, founded on long and extensive observation in various parts of Europe. His conclusions fully accord with the principles of the International Association. He thinks that the system of Measures, Weights, and Coins, ought to be both decimal and universally applicable; that all its parts should have a simple and intelligible relation to one another; and that all the required conditions are fully supplied in the Metrical System, the incomparable superiority of which to all other methods is now established by ample experience.

I take this opportunity of observing, that another new unit may now be added to the list in § I. Mr. E. N. Ayrton, M.A., of Lincoln's Inn, proposes as such the *Yard Royal*, = 40 English Inches.—"Coinage, Weights, and Measures, on a Ten, or Decimal Plan," London, 1858.

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What is the best unit of length? :
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